CENTRAL AREA SYSTEMS STUDY

Volume I

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

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VOLUME I

JUNE, 1971

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THE CASS REPORT

This is Volume I of four volumes which comprise the report on the entire Central Area Systems Study (CASS).

The CASS Project was a major study of the Authority's Central Subway and "Green Line" Streetcar System, carried out as a combined effort of Authority staff personnel and engineering consultants. Although the major emphasis was on the Central Area and the Riverside Line, the study was expanded to include consideration of possible future extensions of the Green Line in the Western Corridor and the Blue Line in the Northeast Corridor.

The Authority has applied to the State and Federal Governments for the necessary funds to implement the recommendations contained in Volume I.

The four volumes are described below:

	Description	Prepared By
Volume I	The CASS Report, covering the entire study, and recommending a course of action.	Authority Planning Staff
Volume II	Engineering Feasibility and Cost Estimates for the Central Area and Western Corridor.	DeLeuw, Cather & Company
Volume III	Graphics to accompany Volume II.	DeLeuw, Cather & Company
Volume IV	Engineering Feasibility and Cost Estimates for the Northeast Corridor, with Graphics.	Colonel S. H. Bingham Associates, Inc.

Walworth B. Williams
Project Manager-CASS
June, 1971

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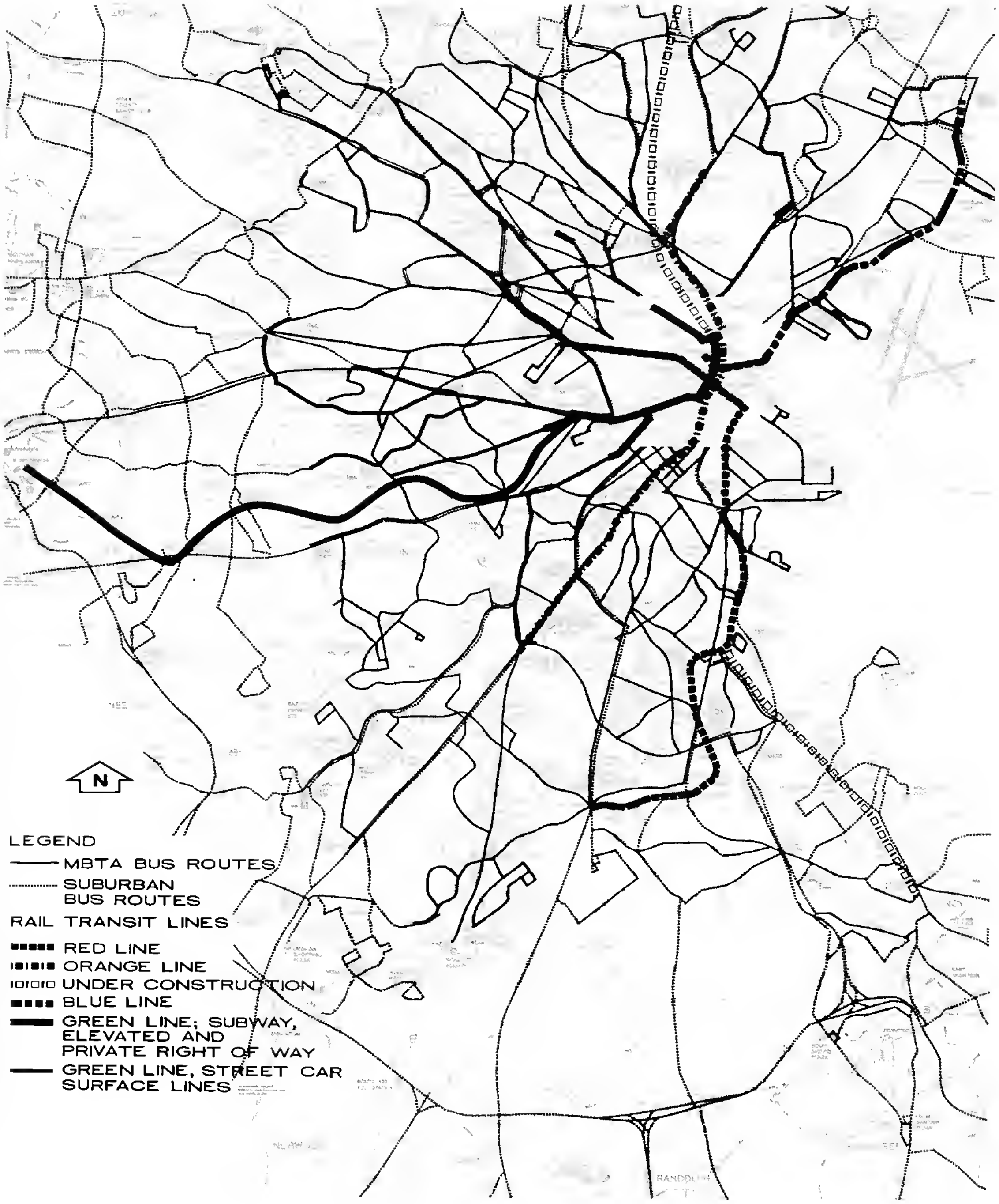
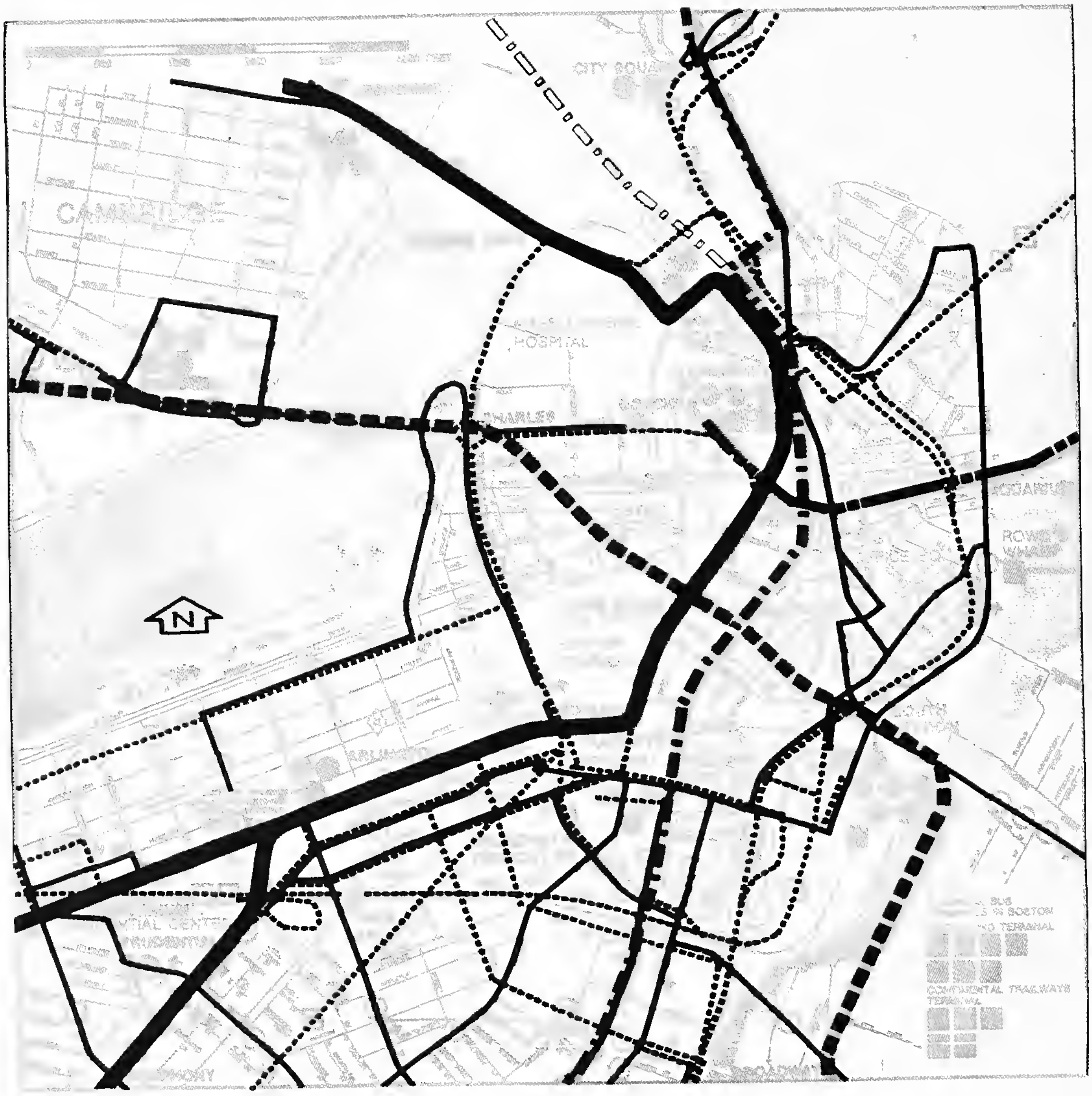


Fronticepiece A

THE MBTA SYSTEM



LEGEND
MBTA BUS ROUTES
SUBURBAN BUS ROUTES

RAIL TRANSIT LINES
RED LINE
ORANGE LINE
ORANGE LINE UNDER CONSTRUCTION
GREEN LINE
BLUE LINE

Fronticepiece B

THE MBTA DOWNTOWN SYSTEM

SUMMARY AND RECOMMENDATIONS

The following pages summarize the results of the Central Area Systems Study (CASS) project. This major study project was conducted by the Authority's Planning and Development Department, with Federal aid to the extent of 2/3 of the cost, in the form of Technical Study Grants from the Urban Mass Transportation Administration.

The CASS research has developed a course of action for the Authority to follow in modernizing its vital Green Line (streetcar system). The study was expanded to cover the Blue Line (East Boston rapid transit line), and recommendations for modernizing and extending that line are also included.

The central conclusion of the CASS project is that the Green Line will serve the public best by retaining its present type of low-platform "streetcar type" service, and that this service can be expanded and modernized, with adequate capacity to meet the needs of the metropolitan community at least until 1990. This can also be accomplished at far less cost than would be incurred if part or all of the Green Line were converted to high-platform type rapid transit service.

The physical condition and performance of the Green Line, and especially the PCC type streetcars currently in use, are such that the highest priority should be assigned to implementation of the following recommended program, known as the "Stage I Program":

> Acquire 220 new air-conditioned "Light Rail" surface-subway cars as described in Chapter 10, to replace the entire fleet of PCC cars. (The quantity of 220 cars was based upon certain assumptions as to size, configuration, and performance characteristics of the cars, as well as a hypothetical schedule. It also assumes that streetcar operation on the outer portion of the Huntington Avenue line would be discontinued in favor of buses. This quantity may be revised when more specific information becomes available.)
>
> Carry out major improvements to the Green Line power distribution system, including three new substations, new feeders, and improvements to the trolley system.
>
> Make track and roadway improvements on the Riverside Line, Central Subway, and Lechmere Viaduct. This program also includes installation of emergency crossovers, turnback facilities, and certain station improvements.

Equip the Highland Branch and the Central Subway with a cab signal system and automatic train stop protection. Other improvements in control and communication for the Green Line will include train radio communication, public address systems on trains and at stations, new interlockings with automatic traffic control at principal junctions, and a system of automatic train identification with automatic destination signs at Central Subway station platforms.

Make improvements in track, fencing, platforms, lighting and traffic control on the Beacon Street and Commonwealth Avenue Lines. Construct new passenger shelters at the principal stops.

Widen the median strip on Huntington Avenue between the subway portal and Brigham Circle, (in conjunction with Boston's planned widening of the Avenue). Improvements will include new and wider loading platforms, relocation of the passing track at Northeastern University, fencing, lighting, traffic signals, and a reduced number of motor vehicle crossings. Construct new turnback facilities between Brigham Circle and Heath Street. Acquire 22 new air-conditioned buses to replace streetcars on the outer portions of the line, which presently operates directly in the narrow and congested streets.

Construct a new vehicle maintenance facility at the Riverside terminal. This facility would be capable of carrying out major repairs and overhaul of the entire Green Line fleet.

Modernize the Reservoir Car House to provide for efficient routine inspection, cleaning, and light repairs for a portion of the Green Line fleet.

The estimated cost of the above-described improvements is summarized in the table below:

RECOMMENDED IMPROVEMENTS

GREEN LINE:

A) New Rolling Stock:

220 Surface Rail Cars	$39,600,000	
22 Buses	814,000	
Total		$40,414,000

B) Track and Roadway Improvements

1)	Subway and Lechmere	$2,712,000	
2)	Highland Branch	4,008,000	
3)	Huntington Avenue	1,680,000	
4)	Beacon Street	600,000	
5)	Commonwealth Avenue	600,000	
	Total		$ 9,600,000

C)	Power System Improvements	3,600,000
D)	Signals and Communication	13,920,000
E)	Vehicle Maintenance and Repair Facilities	8,880,000
	TOTAL	$76,414,000

This is the "Stage 1" program. It was arrived at after a great deal of detailed study of many alternative schemes for modernizing the Green Line and increasing its capacity. The schemes were resolved into three major "system solutions" which are described later in this summary and discussed in detail in Chapter 9 of the report. Each of the system solutions includes most of the above program for accomplishment as its first stage; hence the term "Stage 1" program. The Authority staff believes, however, that adoption of the full Stage 1 program will produce the best overall results for the foreseeable future (at least until 1990), and that it will not be necessary or desirable to proceed to later stages of any of the system solutions unless traffic demands greatly exceed the levels now anticipated. In that event, the Authority could elect to proceed with any of the three system solutions, since the Stage 1 program is the same for all three. The three systems may be thought of as "Post 1990 Systems."

Stage 1 does not represent <u>everything</u> that should be done for the Green Line. Certain improvements at individual locations and stations are needed, but should be deferred until there has been an opportunity to evaluate the effectiveness of the Stage 1 program. In addition, the design of the Light Rail Vehicle should allow for moving step mechanisms to be added at a later date. Thus, after the effectiveness of Stage 1 Improvements has been analyzed, the Authority holds open the option of raising platform heights in major downtown stations if operating conditions demand. Also, opportunities will arise to carry out minor improvements which are not now specifically included in Stage 1.

JUSTIFICATION FOR THE STAGE 1 PROGRAM

The Green Line has serious problems which affect its performance in terms of capacity, speed, reliability, comfort, and operating cost. This network of subway, surface, and elevated routes is operated entirely with a fleet of aging streetcars of the "PCC" type. The facilities for control, communications, and vehicle maintenance can only be called primitive by today's standards, especially when one considers that the Green Line is the backbone of the entire MBTA system, serving as a major feeder and distributor for the other transit lines, and carrying many more daily riders than any of the other three major lines.

To the average rider on the Green Line, the need for new vehicles and a general upgrading of facilities is only too painfully obvious, and it would hardly seem necessary to conduct a major study in order to decide what should be done. Such is far from the case, however. The Green Line of today is a very sensitive organism which fills a triple role of feeder, trunk line carrier, and downtown distributor. It is really a network of lines, performing several different jobs at once. It is precisely because of the complicated nature of its functions, that it has been so difficult to come up with a solution which will solve the major problems without adversely affecting the diversified service which this unique line performs. These complications also help to explain why so little has been done in recent years to modernize the Green Line network; the best course of action has been far from clear.

The CASS Project studied in depth all of the major schemes for improving the Green Line which seem to have merit, some of which have been advanced repeatedly for a number of years without serious analysis. A course of action has now been made clear by the CASS Project. That is, in a few words, "Stay with the existing system, but improve it."

Chapters 5 and 7 contain detailed analyses of the "Inner Cities Area" and the nature of the neighborhoods served by the Green Line. It was revealed that the core area of service is much larger than usually realized; certainly much larger than the "Central Area" as defined at the beginning of the CASS Project. The Green Line serves a very significant portion of the Inner Cities Area.

The Green Line "organism" can be broken down into component parts with different functions:

Commonwealth Avenue and Beacon Street surface lines are local collector lines, serving a densely populated linear residential area, whose residents are downtown oriented, and heavily dependent on public transportation.

The Huntington Avenue surface line is really an extension of a downtown distribution system, serving an area of intense educational, medical, and cultural activity. The outer end of this line (beyond Heath Street) is like a separate line, serving as a local collector, but doing a poor job because of severe street congestion in the portion where the streetcars do not have the benefit of a reservation.

The Riverside Line (or Highland Branch) is inherently a high-speed commuter trunk line, trying to do the job with low-speed equipment. It is entirely grade-separated, and is the longest line on the MBTA system (9.4 miles from the subway portal) and the only one which extends to the circumferential highway, Route 128.

The Central Subway serves all four surface lines, and gives them the great advantage of offering a one-seat ride to downtown (without transfer), and distribution through the spine of the Central Area, and to the other three rapid transit lines which it intercepts. Besides this, the Central Subway performs a vital shuttle service for intra-downtown area riders.

The Lechmere Line is really an extension of the Central Subway, serving as a feeder, but due to its short length it depends heavily on feeder bus routes for its existence.

Many people today think of the "trolley car" (a surface rail car designed for low-level platforms) as obsolete and old-fashioned; and so it is, wherever it has to operate in the streets and mingle with motor vehicle traffic; but in Boston, with its unusual system of surface lines in reservations, feeding directly into a subway, the "streetcar" is potentially a far more versatile vehicle than the "conventional" rapid transit car.

Conventional rapid transit lines are thought to be more efficient and less costly tooperate than low-platform car lines. This is true if one considers only the cost of operating the line itself, and if peak volumes are high. But here in Boston, peak volumes are not very high (as compared to cities like New York and Chicago). Peak loads are being handled with 4-car trains on the rapid transit lines. Work rules and state crew laws tend to defeat much of the inherent advantage of high-platform

rapid transit. But more important is the fact that the three rapid transit lines (Red, Orange and Blue) depend heavily on costly and money-losing feeder bus lines for their life-blood, whereas the Green Line performs most of its own collection and distribution service. Moreover, the three rapid transit lines are highly dependent on the Green Line's Central Subway for downtown distribution, and to areas in Back Bay, Brookline, Brighton and the Fenway.

In terms of the number of people served, the Green Line's Beacon Street, Commonwealth Avenue, and Huntington Avenue operations are far more important than the much longer Riverside Line.

The CASS traffic studies have shown that conversion of the Riverside Line to high-platform, high speed operation would attract a great deal more traffic by 1990. Connecting the Riverside Line to the Blue Line, creating a through route from Riverside to Wonderland, would attract even more riders, and give the Blue Line much better downtown distribution. But engineering studies have shown that there is no easy way to convert the Riverside Line without disrupting the very vital ridership patterns that now exist, and running the risk of a major loss of local riders.

Conversion of the Riverside Line to high-platform rapid transit operation is a problem that goes far beyond the purchase of new cars, and raising the platforms at stations. Conversion of this line would require either rerouting the downtown portion to remove it from the Central Subway and separate it from the rest of the Green Line, or conversion of the entire Central Subway to high-platform operation. The latter choice would mean cutting off the Commonwealth Avenue, Beacon Street, and Huntington Avenue lines, forcing transfers to the Central Subway unless the Light Rail vehicles were operated with dual-level platform capability. It would not be feasible (or even desirable) to convert these surface lines to "pure" high-platform operation.

Rerouting of the Riverside Line could be done in two different ways, but either one has serious disadvantages. The capital cost of any of the choices would be extremely high, and would primarily benefit the Riverside Line at the expense of other portions of the Green Line network.

As mentioned above, a tunnel connection between the Riverside Line and the Blue Line was considered, but this would have required conversion to high-platforms, and a different system of power pick-up. In view of the high cost of such a connection, it was apparent that the benefits gained in better distribution within the Inner Cities Area, and inter-corridor riding, would be offset by the disadvantages and problems of conversion to high-platforms mentioned above.

The three system solutions, which involve conversion to high platforms, are described later in this summary and are discussed in detail in Chapter 9 of Volume I. The Engineering Consultant, DeLeuw, Cather & Co., is of the opinion that the pressure of population and traffic demand will eventually force conversion to high-platform operation and therefore will require adoption of one of the system solutions which they studied in detail. Nevertheless, they advocate the immediate adoption of the Stage 1 program (which is the same for all three system solutions), as the only practical means of achieving immediate improvement for the Green Line.

The Authority staff not only advocates the adoption of Stage 1, but believes that this program is actually preferable to the much more costly construction required for the later stages of any of the system solutions. It believes that traffic demand is not likely to exceed the ability of the Stage 1 system to handle it before the year 1990. It is quite likely that none of the Green Line stations will develop sufficient activity by 1990 to require raising of the platforms. In Chapter 9, it is pointed out that the line volume between Boylston and Arlington Stations in 1964 was 59,000 one-way passengers per day. The highest 1990 forecast determined for this link is 64,000 (for System 3). Station boardings at Arlington are forecasted at 19,300* for 1990 System 3, compared with about 15,600 average daily boardings in 1970. These volumes might be difficult to handle with low-level platform equipment, but the forecasts assume the conversion to high-platforms and the existence of the through connection to the Blue Line; in other words, they assume the highest development of the Green Line. If these improvements are not made, the demand will be correspondingly lower. For example, the 24-hour 1990 boardings for Arlington Station forecasted for the base system (Green Line as it exists today) would be 16,800.*

The advantages of low-platform operation are its relatively low first cost and its great flexibility. All that is needed for a stop is a strip of blacktop, and stops can be located as close together as necessary. On-board fare collection makes it

*These numbers have been increased over those produced by the downtown assignment model to allow for intra-downtown trips, which are not included in the model output. See Volume I, Table 9-1.

unnecessary to man the stations or to build elaborate structures and fencing to prevent evasion of fares. Except in areas of very heavy traffic, expensive pedestrian overpasses and underpasses are not necessary. Rail lines can be extended when traffic warrants, with a minimum of construction costs and space requirements.

On the other hand, low-platforms do require longer stop times for loading and unloading, and the existence of step wells in the cars reduces the available passenger space and complicates the design of the vehicles.

Automatic on-board fare collection may become practical in the future, but until it does, the crew requirements for a train of more than two low-platform cars would be greater than for a high-platform rapid transit train. High-platform trains, however, require all stations to be manned. (It is recognized that in some cities, such as Cleveland, on-board fare collection is done with high-platforms using specially designed cars, but such operation is confined to single cars at off-peak hours.)

THE "NO. 6" VEHICLE STUDY

The state of transportation technology today is such that no better vehicle than the modified streetcar exists for performing the flexible, frequent service which is needed to tie the Inner Cities Area with the Central Area, or "downtown." Since the PCC cars were built, transit technology has advanced to the point where there is no reason why a car cannot be built which will adequately service the local surface lines, the Central Subway, and also be capable of providing a comfortable ride on the Riverside Line at 55 mph. The Authority's Equipment Engineering Department undertook a study, in conjunction with CASS, to develop performance specifications for Light Rail cars for the Green Line. In addition, The Authority undertook a program to design a prototype car using standard rapid transit components, for bidding by American rail manufacturers. This study of prototype design, and performance criteria is discussed in this report as the "No. 6"project.

The Stage 1 program has set six performance goals, and it is believed the new vehicles and associated improvements will meet all six goals. By contrast, a Green Line which includes high-platform cars would meet some goals better, but others less well, and at vastly greater capital cost. The goals are:

1. Reduce overall travel time.
2. Improve reliability of service.
3. Control cost of operation.
4. Improve safety and security.
5. Increase system capacity.
6. Improve rider and community environment.

The discussion in Chapter 10 shows how each of these goals will be met, and Table 10-2 summarizes which of the Stage 1 improvements will meet which goals.

The proposed new low-level cars will have greatly improved performance characteristics compared with the PCC cars. They will be capable of 50-55 MPH, air-conditioned, quiet, comfortable, capable of operating in either direction, and will have a greatly improved arrangement of doors which should reduce loading and unloading time at stations by more than 15% at right-hand platforms, and better than 50% at left-hand platforms. Running time from Riverside to the subway portal is estimated at 21.2 minutes, and Riverside to Lechmere at 37.6 minutes. This compares with present running times of approximately 28 and 48 minutes, respectively. See Chapter 10 for a description of the proposed cars.

The capability for faster loading and unloading is especially important with the close headways that exist in the Central Subway. The stations which will benefit the most are those with left-hand platforms: Haymarket, Government Center, Park Street (southbound outer track), and Kenmore (outer tracks).

The bi-directional capability will reduce the need for turning loops, and make it possible for the new cars to operate to any point in the system singly or in trains, where they can reverse direction by means of a simple crossover. This will make it easy to establish extra service when needed, or to cope with emergency situations.

In the design of the new cars, much attention will be given to reliability and ease of maintenance. Component parts will be designed for quick replacement, so that repairs can be made with a minimum of out-of-service time.

The traffic forecasts do not indicate that high-platforms will be imperative at any station in the near future. Those stations which are most likely to need high platforms some day would also be the most difficult and costly to convert, so their early conversion could not be justified now. In addition, budget limitations have made it impossible to include platform alterations in the Central Subway in Stage 1. Therefore, it is recommended that the car design permit future modification which would allow the installation of convertible steps if later conditions may demand.

There is a resurgence of interest in streetcar-type vehicles today. The modern electric car can be quiet, comfortable, speedy, does not pollute the air, and wherever it has the benefit of a median

reservation or private right-of-way, it can offer good mass transportation where volumes are not too dense. Furthermore, in such service, it does not contribute to motor vehicle congestion and can operate directly into downtown subways. The motor bus cannot do this, although a dual-mode vehicle (road-or-rail) is a dream that may someday be realized.

There are highly successful streetcar lines in several European cities, and such North American cities as San Francisco, Philadelphia, Pittsburgh, and Toronto have shown interest in revitalizing their streetcar systems. San Francisco is ordering a new fleet of cars.

A word of caution is needed here--wherever streetcars are forced to operate directly in the streets without the benefit of any type of reservation, as they did in the horse-and-buggy days, they simply cannot compete with motor vehicle traffic. Serious delays and tie-ups are inevitable. In Boston, this condition prevails on the outer end of the Huntington-Arborway Line and its effects are felt in service irregularities throughout the Green Line network. Buses are now operating on the Watertown Line in place of streetcars because that line was formerly subjected to the same type of problems.

THE RELATED STAGE 1 IMPROVEMENTS

It is absolutely essential that acquisition of the new vehicles be accompanied by corresponding improvements in power supply, track, roadbed, signalling and communication, and maintenance facilities. As pointed out in Chapter 10, the new cars simply cannot be operated without the recommended "beefing up" of the power supply and distribution system. Failure to carry out the other improvements would prevent the new cars from giving the good performance of which they are capable.

It would be unsafe and uneconomical to install a new fleet of high-performance cars on the Riverside Line without the benefit of modern automatic train stop protection and cab signals. Such protection would not be required on the relatively slow-speed surface lines (Commonwealth, Beacon, Huntington), but the basic principles of safety require that any train-stop system for the Riverside Line should include the Central Subway as well. It follows, then, that any remaining PCC cars which mingle with the new cars in the subway or which may occasionally be dispatched to the new shop at Riverside, would have to be equipped with the same protective devices as the new cars.

If it were decided to acquire, say, 100 new low-level cars instead of the recommended 220, the cost of the recommended

package could be reduced about $20 million (from $76.4 million to $56.4 million). This would include about $1 million which would have to be spent on the remaining PCC cars to equip them for automatic train stop protection and cab signals (see Chapter 3 of Volume II). If this were not done, it would probably be necessary to restrict the speed of the new cars until such time as the remainder of the PCC cars were retired.

It is strongly recommended, therefore, that a full fleet of new low-level cars be acquired in as short a time span as the availability of capital funds will permit.

The report discusses the value of the various proposed communication aids. In particular, it recommends the installation of train radio communication for flexibility in handling unusual influxes of traffic, recovering quickly from service disruptions, coping with emergencies, and for the protection of the public and employees.

The need for new maintenance facilities is emphasized in Chapter 8. Most of the burden of PCC car maintenance now falls on the antiquated and cramped facilities at Reservoir. PCC cars have to be trucked to Everett on flat-bed trailers for major repairs. When the tracks of the Watertown line and the outer end of the Huntington-Arborway line are removed, the Watertown and Arborway maintenance facilities will be isolated. It would not be practical to expand the Reservoir facility, and the only suitable location for a new facility is at Riverside.

The Authority cannot acquire new cars and expect to maintain them in existing facilities. The construction of a new major facility at Riverside is essential, with all the necessary tools and equipment for maintaining the Light Rail vehicles. Construction must be timed so that the shop is ready for use by the time the first cars are delivered. The new facility will of course provide improved efficiency in maintenance of Green Line equipment.

The need for rehabilitation of the track and roadbed on much of the Riverside Line and other parts of the Green Line is urgent. Much of this work would be needed even if there were no plan to acquire new vehicles. There is no point in acquiring new high-performance cars if they are to be operated on an inadequate track structure.

All of the foregoing improvements are required if new rolling stock is to be purchased. The Stage 1 program therefore is a "package deal" which must be kept intact insofar as possible.

THE BLUE LINE

Improvements and possible extensions to the Blue Line (East Boston Line) were studied as part of the CASS project. This was included in the project because it was the only rapid transit line besides the Green Line that was not already undergoing or slated for major modernization and extension. It serves an important sector of the Inner Cities Area, but suffers from very poor downtown distribution because it ends in a downtown stub end at Bowdoin Station. It was deemed important to explore how the Blue Line could be extended at either end, and a connection from Bowdoin to the Green (Riverside) line at Park Street seemed desirable. The three major system solutions that were studied included a link between the Blue and Green lines.

The study has concluded that the Blue-Green link cannot be justified when its cost is weighed against the benefits. It could not be built anyhow, except as an integral part of one of the system solutions, none of which are recommended at this time. The Blue Line will therefore have to operate independently for the foreseeable future.

The Blue Line urgently needs new equipment. It is strongly recommended that the Authority proceed immediately to acquire 32 new rapid transit cars to replace the 48 existing cars built in 1923.

It is also recommended that these cars and the 40 existing cars built in 1951 be equipped with train radio, for the same reasons given above for the Green Line.

The total improvements recommended for immediate action are:

BLUE LINE:

32 new rapid transit cars	$6,400,000
Train radio	600,000
Total	$7,000,000

The acquisition of new cars for the Blue Line was recommended in the Authority's 1966 Master Plan, and the need for them is of course still greater today.

Since the Blue Line is already equipped with a mechanical form of automatic train stop protection, which is adequate, the installation of a new signal system is not recommended at this time.

Studies were made of possible extensions of Blue Line service. These were known as the Northeast Corridor Studies, and Col. S. H. Bingham Associates, Inc. served as the consulting engineers. Their report is contained in Volume IV of the CASS Report.

In studying these possible extensions of service, consideration was given to their effect upon the Central Area portion of the system and its ability to handle the additional traffic that such line extensions would generate.

The Northeast Corridor studies are discussed in Chapter 4 of Volume I. The alternatives that were studied are summarized briefly below:

An extension of the Blue Line from its present terminal at Wonderland in Revere to a new terminal near the Pines River in Revere (a distance of about one mile) with a large parking lot and access roads to Route 107 and Interstate Route 95.

An express rail transit route from Pines River to a connection with the existing Blue Line near Airport Station.

A branch from the existing Blue Line near Airport Station to a new terminal station in the terminal area of Logan International Airport.

There were also some variations of these schemes, which are discussed in Chapter 4.

Traffic forecasts for this corridor have shown that if the extension from Wonderland to Pines River is built, daily inbound Blue Line boardings will increase 87% from the present 23,000 to 43,000 by 1990. This compares with a projected increase of 35% to 31,000 if the extension is not built.

The proposed express line between Pines River and Airport Station cannot be justified because the forecasts indicate it would generate a negligible amount of additional traffic and would save less than five minutes running time from Pines River to downtown. The engineering consultant, Col. S. H. Bingham Associates, Inc., has estimated the construction cost of such an express line at $48,720,000.

Construction of a branch or spur line to the Logan Airport terminal area is not recommended. The engineering consultant reported favorably on the construction of such a spur, but its construction cost was estimated at $26 million for a distance of only 4,000 feet. Construction of a loop track that would serve the individual airline terminals was found to be impossible. Any spur track from the existing Blue Line to the Logan Airport terminal would not be able to provide direct access to the various airline terminals. Thus, many riders would still have to transfer to some other type of conveyance for the last leg of their trip to the airline check-in counter or place of employment. Furthermore, a spur track would result in less frequent service for the rest of the Blue Line north of Airport Station.

The Authority should work closely with the Massachusetts Port Authority to encourage the construction of an elevated "people-mover" system within the Logan Airport terminal area, with a connection to the existing Airport Station.

The Pines River extension is recommended for construction. The extension has not been included with the Blue Line improvements recommended for immediate action for two reasons. First, the need for new cars is very urgent and must take priority over the construction of any extension. The 32 new cars plus the 40 existing 1951 cars would be sufficient to operate the line with the extension, if it is built. Secondly, the Authority staff believes that an adequate extension could be built for considerably less than the engineering consultant's estimate of $28,650,000, if standards of grade and curvature are relaxed somewhat. Since it is not planned to build the express line, it should be possible to construct a single-level terminal station rather than the two-level terminal recommended by the consultant.

If the proposed Revere Beach highway connector is built by the Massachusetts Department of Public Works as part of a coordinated rail-highway plan for the Revere-Pines River area, then the cost and complexity of access roads to the parking area could also be reduced.

It is recommended that the Authority continue working with the MDPW and the City of Revere to develop a coordinated plan for an effective and relatively low-cost rail-highway interface in the Pines River area.

The Pines River terminal, if built in conjunction with the proposed Revere Beach highway connector from Interstate Route 95 and Route 107, and with easy access to good parking lots,

should attract large numbers of North Shore highway commuters to use public transportation from this point to downtown or the airport. It would also offer an attractive opportunity for transfer from feeder buses or B&M commuter trains.

THE SYSTEM SOLUTIONS FOR THE GREEN LINE

Each of the three system solutions, which are discussed and analyzed in Chapter 9 of Volume I and in Chapter 4 of Volume II (the engineering consultant's report), was intended as a long-range program to expand the capacity of the Green Line and to greatly improve the quality of the service in terms of speed, convenience, safety, and comfort. The first stage of all three systems is identical, and it is that first stage that this report is recommending for immediate implementation.

Each of the system solutions involve the conversion of the 9.4 mile Highland Branch, which is the surface portion of the Riverside Line, to high-platform rapid transit operation, with prepayment stations. This would greatly increase the capacity of the line, and cut the running time from the Riverside terminal to the subway portal from the present 25 minutes to approximately 18.5 minutes.

The Riverside Line presently enters the Central Subway near Kenmore Station where its trains mingle with trains from the Commonwealth Avenue, Beacon Street, and Huntington Avenue surface lines. In Systems 1 and 2, the conversion to high-platform operation for the intown portion of the Riverside Line would be achieved by rerouting that line out of the Central Subway. In System 3, the Central Subway itself would be converted to high-platform operation, but the Commonwealth Avenue and Beacon Street surface lines would be cut off, forcing a transfer near Kenmore for each of those lines. In System 3, the Huntington Avenue line would be rerouted via the old Tremont Street Subway and would operate to the North Station via Park Street, Government Center, and Haymarket, with low-platform service as at present.

The Riverside rerouting in Systems 1 and 2 would involve construction of a new subway from Back Bay Station up Columbus Avenue and under Boston Common to Park Street. System 1 would make use of the Penn Central Railroad right-of-way from Fenway Park to Back Bay Station for Riverside trains, while System 2 would utilize the Huntington Avenue subway for this purpose by extending it to a connection with the Highland Branch at Brookline Village.

All three of the system solutions include a subway connection from Park Street Station on the Green Line to Bowdoin Station on the Blue Line, so as to create a through route from Riverside to Wonderland.

The three system solutions are illustrated in Chapter 9 of Volume I, Figures 9-1, 9-2, and 9-3. The individual stages of construction are illustrated and discussed in Chapter 4 of Volume II.

The CASS Study has concluded that there is no practical way of achieving high-platform type rapid transit operation on any portion of the Green Line without enormous expense. Admittedly, it would not be necessary to adopt every feature of System 1, 2, or 3, but the majority of each system would have to be constructed in order to have a workable system. For example, the tunnel connection between Park Street and Bowdoin Stations might be eliminated. The traffic forecasts indicate that this connection, although desirable, would be difficult to justify in the light of its high capital cost (see Chapter 9).

The table below summarizes the construction cost of the three system solutions, as estimated by the consulting engineer (DeLeuw, Cather & Company), and compared with the estimated Stage 1 program.

	$ Millions		
Construction Cost:	System 1	System 2	System 3
As developed by DeLeuw, Cather & Co.	$137.0	$198.0	$180.2
Plus new Riverside Shop and Reservoir Improvements	8.9	8.9	8.9
Plus new cars	45.0	45.0	45.0
	$190.9	$251.9	$234.1
Less Riverside-Blue Line connection	12.5	12.5	12.5
	$178.4	$239.4	$221.6
Stage 1, estimated costs	76.4	76.4	76.4
Excess Cost of System Solutions	$102.0	$163.0	$145.2

From the above table, it can be seen that construction of any of the three system solutions to its final stage would cost 2-1/2 to 3 times what Stage 1 would cost. The estimate for System 1 is low because it does not contain the presently unknown cost of acquiring the Penn Central right-of-way (owned by the Massachusetts Turnpike Authority). The cost of land and right-of-way would be minimal for Systems 2 and 3.

Although all three systems contain an allowance for contingencies, there is always the chance of escalating costs due to unforeseen construction problems. Stage 1, on the other hand, contains very little major construction of the type that could be subject to unpredictable costs.

All of the system solutions would produce a much better and faster line-haul service for Riverside Line patrons. Congestion in the Central Subway would be greatly reduced, and all segments of the Green Line would of course benefit from this. Systems 1 and 2 would both create an excellent transfer facility at Back Bay Station, which would give patrons of the Riverside Line and the new Orange Line Southwest Extension more options for downtown destinations. System 3 would greatly increase the capacity of the Central Subway itself. There are other advantages too numerous to discuss in the summary.

However, each of the system solutions has drawbacks too. Aside from the many technical problems of implementing these systems while maintaining traffic, each system tends to disrupt existing service patterns which the CASS Study has shown should be maintained and promoted. For example, System 1 would eliminate a potential corridor for expanded inter-city railroad service. System 2 would destroy the excellent local distributor service now performed by the Huntington Avenue surface line in the busy Fenway area. System 3 would truncate the Commonwealth and Beacon surface lines, forcing a highly undesirable transfer. All three systems would tend to reduce the service in the Central Subway, probably requiring some form of shuttle service for intra-downtown riders.

The big advantage of high-platform operation is its ability to handle much greater volumes of traffic. Conversion to high-platform operation would tend to attract greater volumes, but the complications of making the converstion which are discussed in this report would tend to negate some of this advantage. If conversion is not made, it is not expected that volumes will exceed the ability of an up-to-date low-platform system to handle them between now and 1990. Chapters 9 and 10 contain tables of estimated operating costs for the present Green Line, the Stage 1 program, and the three system solutions. The annual operating cost of the Green Line after adoption of the Stage 1 program is estimated at $17.2 million, compared with $20 million for the present operation.

The Authority should evaluate the results of the Stage 1 program, and remain alert to adopt new technology when it can be applied to specific solutions beyond the Stage 1 program. No recommenda-

tion is made at this time to proceed with later stages of any of the system solutions. The options should be kept open until the results of Stage 1 can be evaluated. The effects of the Orange Line Southwest Extension on the Green Line should also be observed before proceeding beyond Stage 1.

POSSIBLE GREEN LINE EXTENSIONS

The study of Green Line improvements was expanded to include consideration of possible future extensions of the Green Line. This part of the CASS Project was known as the Western Corridor Studies. These studies were important in predicting the volume and distribution of the traffic for the Central Area, as well as determining the feasibility of extensions to better serve certain communities and attract more commuters to mass transit.

The Western Corridor Studies are described in Chapter 3. The Engineering Consultant's report for the Western Corridor appears in Chapter 6 of Volume II. The alternatives that were studied are summarized briefly below:

An extension of the Riverside Line from its present terminal at Riverside to Framingham, via the right-of-way of the Penn Central Railroad through Weston, Wellesley and Natick.

Conversion of the present Penn Central right-of-way between Fenway Park and Riverside, via Allston, Newton, and Newtonville to rail rapid transit operation, and continuing to Framingham as above.

An extension of rail transit from the Riverside Line at Cook's Junction near Newton Highlands, into Needham through Newton Upper Falls via the right-of-way of the Penn Central (former New Haven Railroad) Charles River Branch.

Variations of the above schemes were considered and are discussed in Chapter 3.

Study of the Western Corridor revealed that the potential exists for much greater traffic on the Riverside Line. For example, if the Riverside Line were to be upgraded to high-platform rapid transit, rerouted out of the Central Subway via the Penn Central and connected to the Blue Line at Bowdoin via a new tunnel (System 1, Chapter 9), then the 1990 boardings for all Riverside Line stations west of Reservoir would be about 29,000, as compared with 8,000 in 1970. It further appears that most of these riders will be attracted whether or not the Riverside Line is extended, so long as adequate parking is provided.

The primary advantage then of extending rail transit beyond Riverside would be to meet the parking demand, rather than reducing travel time. With the system improvements described above, there would be 12,000 daily boardings at Riverside, and a demand for 7,400 parking spaces. Such a demand would require a huge parking garage, and it is unlikely that adequate access ramps and roads could be provided so as to avoid serious congestion during the peak periods.

Projected parking demand of this magnitude could better be met by a short line extension, with additional parking facilities beyond Riverside. The engineering consultant, DeLeuw, Cather & Company, has estimated the cost of an extension from Riverside to Framingham at $37 million (not including right-of-way costs or the cost of vehicles).

It has been concluded that an extension all the way to Framingham is not needed and cannot be justified. If, however, the Stage 1 program produces encouraging increases in traffic as expected, then the Authority should consider a short extension beyond Riverside to Wellesley Farms, where additional parking facilities could be provided.

The Authority's property at Riverside would lend itself well to air rights development. The area is an ideal focal point for transportation services, including long distance buses, and perhaps helicopters. Construction of the proposed new maintenance facility on part of the present parking area, coupled with an air rights development, would place a severe constraint on the amount of commuter parking that could be provided. However, a multi-level parking garage could be included as part of an air rights development, with a portion of it assigned to commuters. This might serve for a few years until the demand exceeded the capacity of the access roads.

It has been proposed that machinery be set up within the state government for preserving railroad rights-of-way for possible future public transportation needs. The unused portion of the Penn Central right-of-way beyond Riverside is a case in point, and steps should be taken to preserve this valuable right-of-way, perhaps by means of an option, even all the way to Framingham, until the nature of its future use has been clearly resolved.

The possibility of utilizing the present Penn Central "main line" right-of-way between Fenway Park and Riverside for rapid transit was considered. Although this would be a more direct route for the Western Corridor and would provide somewhat faster service than could be provided via the Riverside Line (or "Highland Branch"), it would not be feasible unless the Penn Central were to abandon all operations, both passenger and freight, on this route. See Chapter 6 of Volume II for the discussion of this alternative.

There is currently a revival of interest in high-speed inter-city railroad transportation, and it is recommended that the Penn Central "main line" route be held open for possible use for inter-city rail service to Worcester, Springfield, and New York or Albany.

Study of the proposed extension from Cook's Junction to Needham showed that it would be technically feasible and relatively inexpensive to construct a line from Cook's Junction to Needham Heights. Beyond Needham Heights to Needham or Needham Junction, construction would be costly and difficult. DeLeuw, Cather & Company estimated construction costs at $14 million for the 12,400 feet from Cook's Junction to Needham Heights, and $38 million for the 7,500 feet from Needham Heights to Needham Junction.

The Green Line extension to Needham was studied as a possible alternative to the planned Orange Line extension into Needham via West Roxbury.

The study has concluded that the Town of Needham would be better served by the planned Orange Line extension than by the Green Line via Cook's Junction. For the Green Line route, the provision of adequate parking and good access from Route 128 presents serious problems. The Cook's Junction route would create another Green Line branch and would adversely affect the level of service to Riverside, and the other branches.

If the current controversy over the construction of Interstate Route 95 results in a long delay to the Orange Line extension, good Needham to downtown service could be provided by buses connecting with the improved Riverside Line, or by express buses operating via the Massachusetts Turnpike.

The present express bus service from Riverside to downtown via the Turnpike should be continued and promoted.

GENERAL COMMENTS

A major question of policy that keeps reappearing throughout the CASS study is the question as to what extent facilities and transit lines should be built or improved <u>in response</u> to demand, and to what extent they should be built or improved to <u>create</u> demand. The two factors are always interacting and can never be clearly separated in making decisions on capital expenditures. Any construction proposed by this report will be in competion with numerous other Authority proposals, when it comes to securing capital funds. Because the present competition for funds is so great, the recommendation for immedi-

ate capital outlays resulting from this study is primarily directed towards meeting urgent existing problems. The beauty of the Stage 1 program is that it does not preclude taking further steps if and when the demand requires them, or when public policy is directed toward building further demand for mass transportation with less concern for construction costs.

The CASS traffic studies have shown that at many locations the demand exists for much more parking if the facilities are adequate and easy to reach. If not, potential riders will go to another facility, use another mode, or won't make the trip at all. The Authority should adopt a continuing program of improving and enlarging parking lots on all lines, providing new lots where needed, and actively promoting use of our system by park-and-ride patrons.

Good maintenance equipment, such as snowplows, line cars, track maintenance equipment, and emergency vehicles, is an essential part of any modernization program. The CASS Project makes no specific recommendation in this area because it is covered elsewhere in the Authority's Program for Mass Transportation. Modernization of this equipment is essential to the full success of the Stage 1 program, but expenditures for such equipment are not part of the Stage 1 program.

The Authority should continue studies of further service improvements beyond Stage 1. As a result of the CASS Project and development of the downtown traffic assignment model, there is now a much greater in-house ability to test the effect of various alternative improvements. Some of these possible improvements are discussed in Chapter 11. High priority items are the elimination of Copley Junction and the Causeway Street elevated structure, major improvements at Park Street and Boylston Stations. Ways may be found to extend streetcar service in areas where it could perform well, such as beyond Lechmere into Somerville.

Studies so far have failed to demonstrate a clear need for an extension beyond Lechmere, but this situation could change. Various alternatives for substitute bus routes to replace the Lechmere car line (and hence permit the elimination of the Causeway Street elevated structure), have been studied. While these might suffice for today's needs, they might not be adequate for the future. Therefore, the Lechmere line should remain as-is until its future is more clear. Completion of the Orange and Red Line extensions to Oak Grove and Alewife Brook will also have an effect on service patterns in the Lechmere-Somerville area.

The Authority should continue to explore the possibilities of applying new technology to the solution of specific Central Area problems. Chapter 11 discusses such things as dual-propulsion vehicles, dual-mode vehicles, dial-a-bus service, air cushion vehicles, and various types of "people-movers." A successful dual-mode vehicle might provide some answers to our Lechmere problem.

As a public operating agency, the Authority must be conservative in adopting new and untried technology, but it seems likely that specific applications can be found for some of these new vehicles and devices. They could contribute significantly to lower-cost solutions to some of our Green Line problems.

TOTAL RECOMMENDED EXPENDITURE

Green Line (Stage 1)	$76,414,000
*Blue Line (New Cars and Radio)	7,000,000
Total:	$83,414,000

*Construction of the Pines River extension is also recommended, but not until a more practical and less expensive plan has been developed in coordination with the MDPW and the City of Revere.

ACTION TAKEN TO DATE

As of May 1971, the Authority has pending with the Urban Mass Transportation Administration a preliminary application for a Capital Grant of $36,000,000, to cover 2/3 of the cost of a $54,000,000 program, which covers most of the "Stage 1" program recommended herein. A request for the necessary 1/3 in matching funds is pending with the Massachusetts Legislature. The present application provides for a partial fleet of new Green Line cars, rather than the full fleet recommended by the CASS Project. It is expected that funds for additional cars will be requested in subsequent applications.

A $31,500,000 request, covering 32 new rapid transit cars for the Blue Line, and extension of the Blue Line to Pines River, is also pending with the UMTA and the State Legislature. The ultimate design of the extension will probably vary somewhat from that recommended by the consultant in Volume IV of the CASS Report.

A preliminary application for a Technical Studies Grant has also been filed with the UMTA. If approved, it will help finance the cost of studies covering Improved Transit Service for Somerville, including possible improvements or extension to the Lechmere Line. Also included will be a joint study with the University of Massachusetts of a Transit Shuttle Service to the new Boston Campus, which could include a "people-mover" type of system. The Authority is continuing discussions with the Massachusetts Port Authority regarding development of a similar system for Logan International Airport.

The Authority is working with representatives of the UMTA and a German manufacturer of light surface-subway rail cars, to set up a Demonstration Program whereby one or two of the latest type German articulated light-rail cars could be brought to this country and tested in revenue service in Boston and several other cities which have expressed an interest in such a program. Such a test could go a long way to determine the suitability of this type vehicle for service on the Green Line and to identify good and bad design features prior to preparing final specifications.

ACKNOWLEDGEMENT

The CASS Project Manager appreciates the energetic and patient assistance of the various representatives of the CASS Project's principal consultants:

DeLeuw, Cather & Company
Colonel S. H. Bingham Associates, Inc.
Peat, Marwick, Mitchell & Co.
Metropolitan Area Planning Council

The cooperation and assistance of the many members of the Authority's staff in the Departments of Planning and Construction, Operations, Transportation, Engineering and Maintenance, and Equipment Engineering and Maintenance is also gratefully acknowledged.

INTRODUCTION

THE CASS PROJECT

The term "CASS" is an acronym for "Central Area Systems Study." This is the name of a transit technical study project which has been carried out under the guidance of the Planning and Development Directorate of the Massachusetts Bay Transportation Authority, with assistance in the form of a Technical Studies Grant from the Urban Mass Transportation Administration of the United States Department of Transportation.

The CASS Report consists of four volumes.

Volume I

A comprehensive report on the Project prepared by Authority staff and written by members of the Planning and Development Directorate.

Volume II

Report of the Engineering Consultant, covering the Central Area and the Western Corridor.

Volume III

Drawings and maps to accompany the Engineering Consultant's report on the Central Area and the Western Corridor Studies.

Volume IV

Report of the Engineering Consultant on the Northeast Corridor Study.

Volume I contains the Authority Staff's recommendations and conclusions, based upon Authority Staff studies, the data produced by the Traffic Consultant, and the findings of the Engineering Consultants.

The report contains only summaries of the traffic forecast data, the socio-economic data, and the engineering cost estimates. The base data is on file in the Planning Directorate offices.

Many of the recommendations herein have been included in a planned revision to the Authority's Program for Mass Transportation, for which additional funds have been requested from the Massachusetts Legislature.

The Central Area Defined

The reader is referred to the frontispiece, which shows the MBTA system, with the four rail rapid transit lines shown in their respective code colors. Extensions currently under construction are shown by broken lines.

The Authority's application of May 27, 1968 to the Urban Mass Transportation Administration for a Technical Studies Grant stated:

> "The Central Area may be roughly defined as that area enclosed within the route of the proposed 'Inner Belt' highway (Interstate 695). The project however includes consideration of all surface streetcar lines which feed into the Central Area."

The reference in the application was to the proposed route of the Inner Belt as projected by the Massachusetts Department of Public Works. The questions of the Inner Belt routing and whether it should be built at all have been matters of continuing heated controversy. As of today, the proposed Inner Belt cannot be used to define the specific boundaries of any area.

The Traffic Consultants, Peat, Marwick, Mitchell & Co., in one of their reports for the CASS Project entitled "Downtown Rapid Transit Distribution System Study," used the word "Downtown" rather than "Central Area." For the purposes of their traffic assignment technique, it was convenient for them to define "Downtown" as that portion of Boston Proper bounded by the Charles River, the Harbor, the Fort Point Channel, and Massachusetts Avenue. The collector stations on the various existing transit lines, which form the "gateways" to PMM's "Downtown" are Maverick, City Square, Lechmere, Kendall, Kenmore, Northeastern University, Dudley, and Broadway.

The Central Area concept, although lacking the benefit of precise boundaries, was a useful one for studying engineering solutions to the major Green and Blue Line problems, since the great majority of the major subway and elevated construction falls within this general area.

The Downtown, or "Boston Proper" concept, representing only a slightly smaller area, was ideal for the development of Peat, Marwick, Mitchell's Downtown Distribution Assignment Technique.

It became evident during the course of the study, however, that both the Central Area and Downtown concepts were too artificial to be useful when discussing the present and potential service areas of the Green Line network and the Blue Line. When the Authority staff studied the nature of the various communities which are transit oriented and held together by social and economic ties, the real nature and extent of the Green-Blue Line service area became evident. This has been called the Inner Cities Area and is discussed in Chapter 5. The Inner Cities provide a rich market area for an improved Green Line network, and to a lesser extent for an improved Blue Line.

The Central Area Problem

Boston's Central Area is relatively well served by rail transit, but the Blue and Green Lines have special problems. The Blue Line lacks good downtown distribution. The Green Line is really a system of lines. It tries to perform the multiple services of a trunk line feeder, a local feeder, and a downtown distributor. That it succeeds at all on this multiple mission is a credit to its designers and operators. It carries out its daily chores with a fleet of obsolescent PCC-type streetcars, an ancient and overtaxed system of power distribution, and a rudimentary system of control and communication.

The Goals

Referring again to the original Federal Aid Application in May 1968, the following statements were made:

> "The CASS Project is intended to supplement the Program for Mass Transportation by providing a thorough analysis of the Central Area portions of the transit system resulting in recommendations for (a) immediate action improvements, and (b) long-range improvement programs which will insure that the Central Area portions of the system be modernized and upgraded in capacity and quality of service consistent with the objectives of the Program for Mass Transportation."

> "The Central Area portion of the system must be made adequate to handle the traffic generated by the line extensions and by the growth of the urban community, at least through the year 2000. It is anticipated that the various recommendations developing out of the CASS Project will be adopted and made a part of an updated future Program for Mass Transportation."

The CASS Project recognized that many improvements were planned and some already were under construction for the Red and Orange Lines, consistent with the 1966 Master Plan. Although not specifically excluded from the Project, CASS planning for these two lines was limited primarily to consideration of provision for better downtown distribution and greater capacity by facilitating interchange between these lines and the Blue-Green Lines.

Boston is fortunate that her Central Area is well served by rail transit. Portions of the Central Business District are somewhat isolated, but in general the coverage is good, with stations closely spaced and transfer between lines relatively simple.

It has been the policy of the MBTA and its predecessor, the Metropolitan Transit Authority, to maximize the use of the existing rail facilities by orienting bus routes to feed the rail system at outlying terminals with convenient transfers from bus to rail. Because of the narrow and congested streets, the City of Boston also has a policy of opposition to the establishment of any new bus routes in the Central Area, except in cases where a marked improvement in service can be demonstrated.

Because of these policies, the CASS Project has concentrated on improvements to the existing rail system as the best avenue for reaching its goals.

Although the Authority recognizes that there is always room for improvement in personnel organization, administration, supervision, and training of operating personnel, these areas could not be made a part of this technical study project. During the course of the CASS Project, a number of managerial and supervisory improvements have been tested and put into use. It is hoped that intensive efforts in these areas will continue.

Another goal not mentioned in the original application, but which was inherent in the supplemental studies for the Western and Northeast Corridors, was to determine whether line extensions

in these corridors should be built, and if built, would the downtown portions of the system be able to handle efficiently the additional traffic generated.

A goal which was not originally stated but became increasingly evident as the study progressed was that the final recommendations ought to be such as to preserve the vital "triple function" of the Green Line as (a) a downtown distributor for the other transit lines, (b) a trunk line for the Western Corridor, and (c) a local feeder and distributor along the principal avenues in the inner portion of the Western Corridor.

The Corollary Goals

There follows a list of goals which are corollary to, but no less important than the central goals discussed above. In establishing these goals, a distinction has been made between those which primarily benefit the Authority as an operating public agency and those which are of primary concern to the traveling public.

The goals of this study which are most useful for the Authority are:

1. Development of an improvement program which recognizes that our product is a service. Capital investment in the physical plant is of questionable value unless it results in a definite improvement in service to the public.

2. Development of a process of planning, construction and service improvements which can be implemented in manageable increments; a process that is evolutionary and can take advantage of opportunities for reducing costs and improving service.

3. Development of a service strategy that minimizes the difficulty of transferring.

4. Establishment of a planning strategy that keeps options open for introduction of new technology.

5. Recognition of varying political values and points of view.

The objectives of the Project, which are most important from the public's point of view, are listed below. Throughout the report many specific problem areas are discussed. Various solutions are proposed; others have been studied and rejected. Every one of the recommended solutions, however, meets one or more of the following objectives.

1. To reduce overall travel time.

2. To improve the reliability of the service.

3. To control cost of operation.

4. To improve safety and security.

5. To increase system capacity.

6. To improve passenger and community environment.

CHAPTER 1

DESCRIPTION OF THE CASS PROJECT

BACKGROUND

Following approval by the MBTA Advisory Board of the Authority's Program for Mass Transportation, or "Master Plan," in September 1966, an intensive effort got underway to implement the extension and improvement projects outlined in the Plan. The Planning staff turned its attention from preparation of the Master Plan to localized planning studies related to the individual line extensions.

The Authority was also committed to study those areas which were only touched upon in the Master Plan. Foremost among these was the question of what to do with the Green Line streetcar network to bring it up to a standard whereby it could provide a level of service comparable with that projected for the new rapid transit extensions. The Blue Line presented a similar but less critical problem.

The Authority Planning staff suffered some attrition following publication of the Master Plan, and since planning connected with the approved construction projects had to take precedence, the planning for the Blue and Green Lines declined temporarily to relatively low priority.

PRE-FEDERAL AID EFFORTS

In March 1967, the Authority contracted with Gibbs & Hill, Inc., an engineering consulting firm, to conduct a preliminary study of the Green Line problems. Gibbs & Hill assembled a great deal of information and data on the Green Line and Central Subway. This information was summarized in their report published in July 1967. It included a delay-failure analysis, based on weekly delay reports over a seven-month period. The principal causes of failures and other operating problems of the PCC cars were identified and classified. Proposals were made for better scheduling procedures, and short-range improvements in track, signaling and structures. A file of all available past reports and studies concerning the Green Line, and all the principal engineering drawings of the Central Subway and Green Line stations, was compiled.

Gibbs & Hill's report also included a preliminary engineering study and cost estimate for extension of the Green Line from Lechmere Square in Cambridge to Washington Street in Somerville, which was proposed in the 1966 Master Plan.

Also in the report were some very preliminary studies of an extension of the Tremont Street Subway to the Boston & Albany Railroad right-of-way, a subway to replace the Green Line elevated structure between Haymarket Station and Science Park Station, a subway connection between Brookline Village Station and the Huntington Avenue Line, and an extension from Riverside to Wellesley along the Boston & Albany right-of-way. This extension was studied because construction of a football stadium near the railroad right-of-way in the Town of Weston was being proposed at that time.

Gibbs & Hill's work gave the Authority a valuable data file with which to proceed to an in-depth study of a long-range improvement program for the Green Line system. In late 1967, it was decided that this type of study would be a good candidate for the newly available Technical Studies Grant which had been announced by the Urban Transportation Administration of the Department of Housing and Urban Development.* The Central Area studies were given the status of a separate project, with its own budget and placed in charge of a full-time Project Manager. Plans were laid for a study project which would make the best use of existing Authority talent. It was realized, however, that accomplishing the study entirely in-house was out of the question because of limited manpower and talent in certain areas, and the high-priority nature of the approved construction project. Therefore, a search was instituted for well-qualified technical consultants who could carry a major portion of the study burden. A number of consultants were considered and interviewed, and ultimately three were selected. On May 27, 1968, the application for the Technical Studies Grant was submitted. Approval was received September 6, 1968.

During the months prior to the approval of the Technical Studies Grant, a good deal of planning work went on. Some of the principal activities were:

*The Urban Transportation Administration is now called the Urban Mass Transportation Administration, and is part of the Department of Transportation.

1. Gibbs & Hill's recommendations were discussed with members of the Transportation and Engineering Departments. Some were put into effect, certain others were deferred for more detailed study.

2. In cooperation with the Boston Redevelopment Authority, detailed preliminary designs were worked out for the widening of Huntington Avenue between the subway portal and Brigham Circle. This plan included a wider median strip, an improved track alignment, fewer stops, and better passenger platforms. The improvements were planned as a part of the Fenway Urban Renewal Project.

3. The traffic engineering firm of Bruce Campbell & Associates, working with our Transportation and Traffic planners, prepared a detailed report on the Beacon Street surface car line, between the subway portal and Cleveland Circle. Their report was published in May 1969 and it included recommendations for a large number of minor improvements which in the aggregate should result in improved regularity, comfort, running time, and safety for the partrons of that line. Many of the recommendations concerned street improvements which would have to be carried out by the Town of Brookline or the City of Boston. Some would have to be worked out as joint projects between these communities and the MBTA. Although similar study has not been done for the Commonwealth Avenue Line, many of the Beacon Street recommendations would be applicable to operations on Commonwealth Avenue.

4. The engineering consulting firm of Parsons, Brinckerhoff, Quade & Douglas, Inc., carried out a preliminary design study of an extension of the Tremont Street subway from the present portal at Broadway and Shawmut Avenue to the right-of-way of the Penn Central (Boston & Albany) Railroad. This study had to be carried out promptly and in considerable detail while the South Cove Tunnel for the new Orange Line Southwest Extension was still under design, to determine whether it would be possible to construct both tunnels in their proposed locations. Parsons,Brinckerhoff's report was published in June 1968 and is discussed in Chapter 8.

The foregoing studies added substantially to the data base available to the Federally-Aided Project.

THE FEDERALLY-AIDED PROJECT

In the description of the proposed technical study, which appeared in the Authority's application for Federal aid, the following statement was made:

> "The CASS Project is now moving into a phase where a specific plan for a long-range solution to the Green Line problem is being sought, and this is the project for which Federal aid is being requested."

The study design consisted of six major elements. They are summarized briefly below.

1. A detailed engineering feasibility and cost study of alternate routes for the Riverside Line and the Huntington Avenue Line to get one or both lines out of the Boylston Street subway.

2. Preliminary design of a tunnel to connect the improved and relocated Riverside Line with the Blue Line, and the study of the feasibility and benefits of operating these lines as a through route between Riverside and the North Shore.

3. Recommendation for improvements in track, power, signaling, equipment and stations on the Riverside-Wonderland route and on the remaining portions of the Central Subway and surface car lines.

4. Recommendations on the feasibility of interconnecting any or all of the four major rapid transit lines so as to facilitate centralized maintenance and repair of vehicles.

5. Traffic research and forecasts.

6. A socio-economic study of the Green and Blue Line service areas.

The output of the study was to recommend both short-term or immediate-action improvements, and a long-term program for major upgrading and increase in capacity.

Many and varied proposals had been made over the years for improvement to the Central Area subway system, and in particular to the Green Line network. Few of these proposals had ever been studied in depth to determine their true effect upon system operations and upon the public, both transit users and non-users. Earlier efforts related to the CASS Project suffered from a bewildering array of alternatives, many of which were of doubtful value. Others had obvious merits, but glaring disadvantages also.

One of the reasons why so little had been done in recent years to modernize the Green Line system was the lack of any clearly defined course of action, plus of course a severe limitation of available funds. Opinions on what to do varied widely among community leaders, transportation experts, and within the Authority management itself. Some of the central questions were whether streetcars should be discontinued in favor of buses; whether the 73-year-old Central Subway could be made adequate to serve Boston's needs for the remainder of this century; whether it and/or the Riverside Line should or could be converted to high-platform type rapid transit operation, and how best this could be accomplished. There was also the question of whether the Blue Line service and operations could be improved by making it part of a through route similar to the Red Line or Orange Line. The congestion and unreliable service in the Central Subway was probably the worst problem of all.

In planning the Federally-aided project, it was decided to limit the scope to the in-depth study of a few major alternative solutions which seemed to have the most merit on the basis of what was then known. It was also deemed important not to insert elements into the scope which could duplicate or overlap work being carried on in other areas. For example, improvement plans for the Red Line and Orange Line were well covered under the Authority's approved program of line extensions and station modernization. Consideration of these two lines in the CASS Project therefore was limited to areas of interface with the Blue and Green Lines.

The engineering consulting firm of DeLeuw, Cather & Company was selected to carry out engineering feasibility and cost studies under the first four elements listed above. Wherever possible specific assignments were given to Authority staff to assist DeLeuw, Cather & Company and provide them with data and information. Major inputs were contributed by staff members in

the areas of Plant Engineering, Equipment Engineering, Operations Planning, Transportation and, of course, Planning and Construction.

The firm of Peat, Marwick, Mitchell & Co. (formerly Peat, Marwick, Livingston) was selected to carry out traffic research and forecasting for the project. Peat, Marwick, Mitchell had done considerable previous traffic research for the Authority and for the Eastern Massachusetts Regional Planning Project and the Massachusetts Department of Public Works.

One of PMM's major contributions was to develop a downtown assignment technique, or model, whereby the Authority was not only able to test the various alternative downtown alignments being studied by the engineering consultant, but in the future our own staff will be able to test additional proposed service improvements and alignments by using this technique, and using the Authority's own computer.

When the CASS Project began, the Authority staff was particularly weak in the traffic research area. During the course of the Project, however, our capability has been greatly increased with the wholehearted cooperation of Peat, Marwick, Mitchell personnel, to the point where much traffic research can be carried out in the future without the need for outside consulting assistance. Part of this enhanced staff capability has come about through experience gained by staff members on the CASS Project, and part due to new personnel added to the staff since the Project got underway.

Peat, Marwick, Mitchell presented their findings in two reports; one entitled, "CASS Downtown Rapid Transit Distribution Systems Study," dated December 1969; the other entitled, "CASS, The Automated Corridor Model and its Application to Western and North Shore Corridors," dated February 1970. The product of PMM's work appears in Chapters 3, 4, and 9 of this Volume.

The Metropolitan Area Planning Council was selected to carry out a socio-economic analysis of the Green and Blue Line service area. Their preliminary report was submitted in December 1969 and the final report in July 1970.

During the CASS study period the Authority Planning staff was expanded and the staff capability in the area of socio-economic research was greatly strengthened. The MAPC therefore did not

do as detailed a job as originally planned. The final product in this area is really a joint effort of the MAPC and Authority staff. The product of this work will be found mostly in Chapters 5 and 7 of this Volume.

In June 1969, the CASS Project was expanded to include studies of the feasibility of further extensions and improvements to the Green and Blue Lines in the Western and Northeast Corridors, respectively. The description of these supplemental studies will be found in Chapter 2.

CHAPTER 2

THE CORRIDOR STUDIES

THE SIX CORRIDORS

For the purposes of transportation planning, the Metropolitan Boston Area is divided into six corridors. Both the highway system and the public transportation systems are radial in their general layout, so that the corridor concept is a good one for this metropolitan area.

The six corridors are the Southeast, the Southwest, the Western, the Northwest, the Northern, and the Northeast (see Figure 2-1).

The 1966 Master Plan provided for major transit construction projects in four of the six corridors.

In the Southeast Corridor, the Red Line is being extended over the former Old Colony Railroad right-of-way to Quincy and Braintree. Work on the first leg of this extension is nearing completion.

In the Southwest Corridor, work is in progress on the South Cove Tunnel, which will be the first leg of a relocation and extension of the Orange Line from Forest Hills to Readville and Needham. Due to a conroversy over expressway construction in the corridor, design work for construction west of the South Cove Tunnel has been suspended pending agreement on the joint highway-transit alignment.

In the Northwest Corridor, the Authority has an approved plan to extend the Red Line from Harvard Square in Cambridge to the Alewife Brook Parkway at the Cambridge-Arlington line. Here also design work has been suspended pending agreement with the Cambridge community on the alignment and type of construction.

In the Northern Corridor, work is well advanced on a relocation and extension of the Orange Line from Haymarket Square to Oak Grove at the Malden-Melrose line. Also in the Northern Corridor, the Master Plan called for a short Green Line extension from the present terminal at Lechmere Square in Cambridge to Washington Street in Somerville. Construction on this extension has been postponed pending completion of this CASS study and continuing

THE SIX SECTORS

FIGURE 2-1

studies of the transportation needs of the City of Somerville. In the light of present capital needs and what we have learned so far of the potential demand, any construction of an extension to Somerville in the near future seems doubtful.

The two corridors which received the least attention in the Master Plan were the Western and Northeast Corridors. In each case, the Plan called only for new rolling stock; 90 low-platform surface cars to replace PCC cars on the Riverside Line, and 32 new high-platform rapid transit cars to replace the oldest cars on the Blue Line.

The Staff Supplementary Report to the 1966 Master Plan discussed longer-range development programs for the Western Corridor and the Northeast Corridor.

For the Western Corridor, the program called for consideration of rebuilding the Riverside Line for high-speed transit service and possible westerly extension of the line from Riverside to Wellesley, Natick, and Framingham. Also to be considered was possible use of the Boston & Albany Railroad tracks between Fenway Park and Riverside for new transit service.

For the Northeast Corridor, a possible extension of the Blue Line from Wonderland to a new terminal in the Revere Marshes at a point which would permit a large parking area and access to the new Interstate Route 95 was called for. In addition, the report empahsized the need for long-range plans for better Blue Line downtown distribution to permit improved service for commuters and riders destined for the major recreation facilities and to attract a greater proportion of Airport traffic to the transit system.

The Authority Planning staff undertook to conduct these studies, but it soon became evident that they were so closely related to the Central Area Systems Study that they should be included in that Project itself. Furthermore, a determination of adequate future capacity for the downtown system could not really be made without, at the same time, considering the effects upon the downtown system of possible future extensions of the Blue and Green Lines.

THE SUPPLEMENTAL FEDERAL GRANT

In December 1968, the Authority applied for a Supplemental Technical Studies Grant to assist with the study of the improvements and extensions in these two corridors as described in the

Master Plan. The Supplemental Grant was approved by the UMTA, and the CASS Project was expanded to include the Western and Northeast Corridor Studies. The Project retained its original name, Central Area Systems Study, even though it had been expanded to include these additional areas.

Specifically, the Western Corridor study includes consideration of:

1. Extension of rail rapid transit service over the Penn Central (Boston & Albany) main line from the vicinity of Fenway Park to the present terminal at Riverside.

2. The extension of rail rapid transit over the Boston & Albany main line from the present terminal at Riverside to Framingham.

3. A third element in the study not discussed in the Master Plan was consideration of extension of rail service from Cook's Junction on the Riverside Line into Needham via the former Charles River Branch of the New Haven Railroad, now Penn Central. Such an extension had been proposed in the 1947 Coolidge Report. It was considered worth studying again at this time as a possible alternative way of providing Needham with rail transit service. The existing impasse over construction of the Southwest Orange Line Extension, which includes a branch to Needham, generated renewed interest in the Cook's Junction to Needham Green Line alternative.

In the Northeast Corridor Study, engineering feasibility and cost estimates were made for:

1. An extension from the present terminal at Wonderland in Revere to a new terminal and parking area in the Revere Marshes in the vicinity of Pines River.

2. A possible express rapid transit route from the new Pines River terminal to a connection with the existing Blue Line just north of Airport Station.

3. A short spur line from the existing Blue Line to the Logan Airport terminal area.

Although the engineering feasibility was only studied as far as Pines River, the traffic forecasting process included an alternative which assumed extension of rapid transit service as far north as the Tedesco area in Salem.

An additional contract was made with Peat, Marwick, Mitchell & Co., which included development of an automated corridor model and its application to the Western and North Shore Corridor alternatives. Their report on the traffic studies of these two corridors was submitted in February 1970.* The results of PMM's work on the Western and North Shore Corridors appears in Chapters 3 and 4 of this Volume.

An additional contract was made with DeLeuw, Cather & Company for the engineering feasibility and cost studies related to the alternatives for the Western Corridor. DeLeuw, Cather & Company's report on their Western Corridor studies is contained in Volumes II and III of this report.

For the Northeast Corridor engineering feasibility and cost studies, the Authority contracted with the engineering consulting firm of Colonel S. H. Bingham Associates, Inc. Their report on the Northeast Corridor studies appears in Volume IV of this CASS report.

SCOPE OF THE CASS CORRIDOR TRAFFIC STUDIES

The scope of work for the Western and Northeast Corridor studies was developed from the 1966 MBTA Master Plan, as discussed at the beginning of this chapter. The scope was also based upon the Recommended Highway and Transit Plan, published by the Massachusetts Department of Public Works, Bureau of Transportation Planning and Development, in January of 1969. This highway and transit plan was developed by the Eastern Massachusetts Regional Planning Project and included the transit extensions in the Western and Northeast Corridors, which are covered in this report.

The corridor traffic analyses were conducted to provide rail transit ridership forecasts for alternative systems in the Western and Northeast Corridors. The objective was to evaluate the feasibility of new alignments and extensions of rapid transit lines in these corridors. A major part of this work involved the automation of forecasting techniques prior to the production of traffic forecasts.

The basis for the transit ridership forecasts evolves directly from long-range regional land-use and trip generation-distribution forecasts developed for the BMATS (Boston Metropolitan Area Transportation Study, formerly the EMRPP, Eastern Massachusetts Regional Planning Project) by the same traffic consultant employed in the CASS Project, Peat, Marwick, Mitchell & Co.

*The report is entitled "CASS, the Automated Corridor Model and its Application to Western and North Shore Corridors."

The corridor study forecasts include inbound station boardings and alightments, and the number of trips to each station by access mode (i.e., walk, bus, park-ride, kiss-ride). Traffic forecasts were made for both peak period (7-10 A.M.) and 24-hour period for certain alternatives, and for peak period only for other alternatives due to contract funding limitations. Computer processing was completed for certain alternatives while manual adjustments were made to machine results for other alternatives to reduce project costs.

Obviously, it was impossible to test all possible alternatives and combinations of service. A few representative systems were selected for testing, which are described in Chapters 3 and 4.

CORRIDOR TRAFFIC FORECASTING TECHNIQUE

General

The "corridor study" is an advanced transit usage forecasting technique whereby transit trips are forecast from and to groups of zones having homogeneous transportation and land-use characteristics (generally having one express transit line in common, hence the term "corridor study"). Primary emphasis is placed on forecasting A.M. peak period inbound transit trips, but it is possible to modify the process in order to forecast for any period of time for which a trip table can be produced.

The core of the technique is a set of curves derived from Boston travel data which relates peak period modal split (percentage of total trips from one origin area to one destination area which use transit) to a given set of socio-economic, transportation system, and travel characteristics which describe the interchange being studied. These characteristics are:

- trip purpose;
- income of trip maker;
- ratio of transit travel cost to automobile travel cost;
- ratio of transit door-to-door travel time to automobile travel time; and
- ratio of transit out-of-vehicle time (walking, waiting, transferring) to automobile out-of-vehicle travel time.

The actual steps undertaken in studying a particular transit facility include:

1. Defining the set of origins and destinations which would be affected by the particular facility being studied.

2. Identification of the destination areas which are the prime transit markets for those origin areas and the transit facility under study.

3. Determining the total trips between each origin-destination pair (obtained from regional travel data or projections).

4. Determining and processing sub-modal splits (i.e., probable mix of access modes to stations or stops) for each pair of interchanges.

5. Preparing travel times, costs, etc., which describe each interchange.

6. Calculating appropriate modal splits and multiplying them by total trips to yield transit trips.

7. Summing transit trips over all interchanges and assigning these to transit stations by access mode for the time period considered (peak period or 24-hour).

Step 5 and part of Step 4 were automated by the consultant within the CASS study. Also involved is the linking of the previously programmed portions to the newly automated steps. Up to now, Steps 4 and 5 had been very expensive and time consuming. The data produced in these steps, which are required for computing modal splits, has had to be prepared, keypunched, and input manually to the next steps in the analysis. By utilizing appropriate portions of the coded networks (1990) prepared for the Eastern Massachusetts Regional Planning Project, making selected changes to these networks in order to simulate additional transit alternatives, and adding a minimum number of new features, an automated procedure has been developed which considerably reduces the time and manual effort required to perform a corridor study. This has the advantage of greatly reducing both the possibilities for manual computational errors and the turn-around time for a corridor study.

Description of New Procedure

Basically the new automated procedure requires slight changes in previously used techniques for coding transit and highway times and costs on existing networks. These coded networks serve as basic input for the computation of cost ratios, door-

to-door travel time ratios, and excess time (out-of-vehicle) ratios for specified origins and destinations in specified transit corridors. These data, along with income levels of the trip-makers (obtained from magnetic tapes available from the EMRPP), are the required input data to the present modal split computation program. This automatic retrieval and processing of the data enables the computer to carry out the travel time and cost calculations and eliminate all hand computations and coding at this stage.

The automated procedure involves tracing minimum time paths on the highway and transit networks (via both vehicle and walk access modes to the rapid transit stations) between specified origins and destinations (which may be zones or groups of zones) and computing costs, excess times, and total times encountered on both highway and transit journeys between these origin-destination pairs. Sub-modal splits for these pairs are manually input as before, although ultimately this process too could possibly be automated. A vehicle access link technique, developed and successfully implemented by the consultant during work for the Metropolitan Washington (D.C.) Council of Governments, was then used to determine the correct times and costs to use on the access links. The appropriate travel time and cost ratios were then computed, the incomes of the tripmakers read in, and a complete set of computer-processable output prepared. This output then serves as input to the modal split computation program.

In addition to the obvious advantages of greatly increasing the speed of producing corridor studies and eliminating the arithmetical errors always possible in manual calculations, this technique has the more subtle advantage of enabling the corridor studies to give specific consideration to more origin and destination interchanges than time would permit with the manual method. Thus, the precision is improved.

New Computer Programs

In order to assemble the information required for use of the modal split curves, it is necessary to trace origin-destination paths along the proposed transit networks. The computer programs developed to perform this formerly tedious job are:

COACT, Compute Access Trivalues
CODET, Compute Origin-Destination Trivalues
CRAMS, Compute Ratios and Modal Splits

These programs were written in Fortran IV for the CDC (Control Data Corporation) 3600 Computer. This large computer was chosen for its computational and input-output speed and for its transportation planning program package, TRANPLAN, which can handle a system as complete and large as the MBTA transit system. The MBTA IBM 360 is not large enough, nor does it have the necessary software for this task.

In addition to the above programs, a series of other programs which are concerned with network processing, card editing and record updating have been either written or modified by PMM under contracts with clients other than the Authority. A complete description of the Automated Corridor Model can be found in Appendix A of the consultant report entitled, "CASS, the Automated Corridor Model and its Application to Western and North Shore Corridors," prepared by PMM, dated February 1970.

CHAPTER 3

ALTERNATIVES EVALUATED FOR THE WESTERN CORRIDOR STUDY

DESCRIPTION OF WESTERN CORRIDOR ALTERNATIVES

The following alternatives were studied by the consultant, either prior to or within the scope of CASS, to determine peak period (7-10 A.M.) and daily inbound station boardings by access mode.

Alternative 1

Conversion of the existing Riverside Line (Highland Branch) to high-platform rail rapid transit service with a new downtown alignment connecting to the Blue Line at Bowdoin. The downtown system alignment is the same as that described for Downtown System 1 in Chapter 9, i.e., the Central Subway is served by the surface Green Lines and the Riverside Line is removed from the Central Subway.

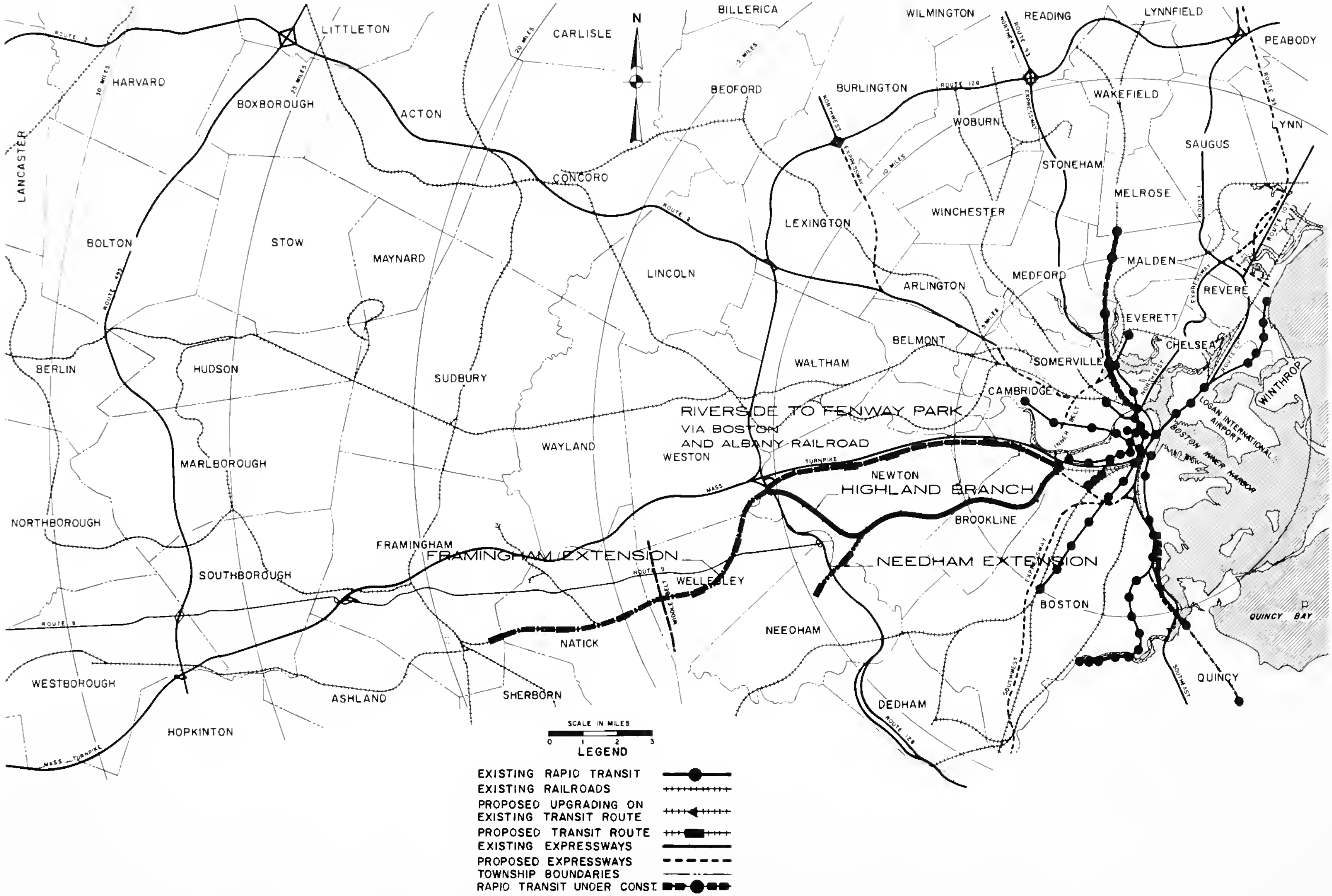
The surface Green Line terminals are Heath Street (Huntington Line), Cleveland Circle (Beacon Line), Boston College (Commonwealth Line), and North Station.

Alternative 2

This alternative is identical to Alternative 1 except the Riverside Line (Highland Branch) is extended from the Riverside terminal to a new terminal in Framingham. The Downtown System is the same as for System 1 in Chapter 9.

Alternative 3

Conversion of the Riverside Line to high-platform rail rapid transit service with an extension to Framingham and a new alignment from Bookline Village Station to Back Bay Station via a new tunnel under Huntington Avenue. The line extends from Back Bay Station to Bowdoin Station. The downtown alignment is the same as that described for Downtown System 2 in Chapter 9, i.e., the Central Subway is served by the Beacon and Commonwealth Avenue Lines, while the Riverside Line combined with the Huntington Avenue Line is removed from the Central Subway. Streetcar service is maintained from Brookline Village Station through the Central Subway.



WESTERN CORRIDOR
Showing Extensions Studied

FIGURE 3-1

Alternative 4

This alternative is comparable to Alternative 1 except the Highland Branch is extended from the Riverside terminal to the Middle Circumferential Expressway in Natick. This alternative represents the recommended long-range Western Corridor configuration described in the "Recommended Highway and Transit Plan" Report, published by the Massachusetts Department of Public Works in January 1969. The forecasts for this system were initiated outside the CASS scope.

Alternative 5

This alternative is referred to in the "Recommended Highway and Transit Plan" Report as the Western Corridor portion of the 1990 "Plan C" network. The Highland Branch remains as a low-platform type service along its current alignment without extension west of Riverside. Conventional railroad passenger service is maintained over the Penn Central (Boston & Albany) right-of-way between Framingham and South Station. Changes to the Highland Branch service are in the form of new rolling stock, track and roadbed improvements. Express bus service is provided from Watertown Square and Newton Corner to Copley Square. The forecasts for this system were made several years ago prior to CASS and the results included here for comparison purposes.

Alternative 6

This alternative is referred to in the "Recommended Highway and Transit Plan" Report as part of the 1990 "Plan A" network. The Highland Branch is as described in Alternative 5. The Penn Central (Boston & Albany) Railroad passenger service is converted to conventional rapid transit between Framingham and South Station. Express bus service is provided from Waltham Square, Watertown Square, and Newton Corner to Copley Square. The forecasts for this system were also made prior to CASS and have been included in this report for comparison purposes.

COMPARATIVE ANALYSIS OF WESTERN CORRIDOR ALTERNATIVES

The results of Alternatives 1-4 show a substantial ridership reduction on the surface Green Lines. This reduction is caused by a combination of two major factors:

1. The rerouted Orange Line (Southwest Project) attracts a substantial number of Huntington Avenue Line riders

due to both truncating the Huntington Line at Heath Street and the superior service of the Orange Line which competes with the Huntington Avenue Line in a common market area.

2. The upgraded, high-platform Riverside Line service attracts a large number of riders from both the Beacon and Commonwealth Avenue Lines.

Previous corridor studies involving the 1990 C (Alternative 5) and 1990 A (Alternative 6) plans did not show the diversion of trips from the Beacon and Commonwealth Avenue Lines to the Riverside Line since the Riverside Line remained as low-platform service through the Central Subway in these alternatives (see Table 3-1). Converting the Riverside Line to high-platform rapid transit and rerouting this service via Back Bay, Park Square, Park Street with a through connection to the Blue Line at Bowdoin, provides a substantial improvement in the Riverside Line service levels.

Analysis of the downtown assignment model results shows a 35% reduction in total downtown travel time and 20% decrease in downtown walk time for Riverside Line riders with this new service. Thus, it is reasonable that a number of riders would be attracted to the new Riverside Line who normally would choose the convenient Beacon or Commonwealth Avenue Lines. Comparison of the 1990 forecasts indicates that instead of a 7,400 daily inbound line volume on the Beacon Street Line, as in Alternatives 5 and 6, there would be only 2,400 in Alternative 4; while on the Commonwealth Avenue Line the inbound line volume would change from 10,500 in Alternatives 5 and 6 to 5,600 in Alternative 4. The Commonwealth and Beacon combined inbound line volume reduction of 9,500 trips (Alternative 4 vs. Alternatives 5 and 6) is reflected in an increase of 9,500 for the inbound line volume on the Riverside Line for Alternative 4 (increase in inbound boardings between Reservoir and Fenway Park Stations on the Riverside Line). The Riverside Line station boardings in Alternative 4 increased dramatically at Reservoir and Brookline Village Stations due to the attraction of trips from the Beacon and Commonwealth Avenue Lines.

The credibility of the forecasts for Alternatives 1-4, which show a substantial diversion of Beacon-Commonwealth Line riders to the Riverside Line, is important in evaluating new downtown systems (see Chapter 9) which would require the Beacon and Commonwealth line riders to transfer to the Riverside Line in

Table 3-1

COMPARISON OF URBAN AREA STATION BOARDINGS AND LINE VOLUMES

Effects of New Orange Line and Riverside Line Improvements on Streetcar Passenger Volumes

	Station Boarding Passengers or Inbound Line Volume (24-Hour)				
Boarding Station or Line	1970	1975	Alt. 4 1990-Rec.	Alt. 5 1990-C	Alt. 6 1990-A
Reservoir	1,330	909	7,473	1,283	774
Beaconsfield	375	375	-	469	414
Brookline Hills	1,665	1,398	2,306	1,521	1,530
Brookline Village	2,030	1,363	5,438	1,398	1,245
Longwood	1,160	501	-	462	448
Fenway	2,690	3,131	4,062	3,048	2,925
Total	9,250	7,677	19,279	8,181	7,336
Beacon Line Portal	11,000	7,097	2,358	7,395	7,154
Commonwealth Line Portal	14,200	10,810	5,613	10,465	10,321
Total	25,200	17,907	7,971	17,860	17,475
SUB-TOTALS	34,450	25,584	27,250	26,041	24,811
Green Street (Orange)	-	3,483	2,774	3,221	3,048
Center Street (Orange)	-	8,162	6,000	6,635	6,442
Roxbury Crossing (Orange)	-	16,008	9,288	13,179	13,162
Northeastern (Orange)	-	6,940	4,410	6,617	5,318
Total		34,593	22,472	29,652	27,970
Huntington Portal (Green)	14,400	2,723	2,324	2,225	6,951
SUB-TOTALS	14,400	37,316	24,796	31,877	34,921

Notes:

1970 boarding counts include both inbound and outbound boardings. 1970 inbound line volumes include trips originating in Western Corridor and other corridors.

Future year forecasts do not include outbound boardings or trips originating from other corridors.

1975 is the same system configuration as 1990-C.

Alternatives 1, 2 and 3 not included here since volumes are approximately the same as Alternative 4 for boardings east of Reservoir Station.

the Kenmore Square area due to conversion of the Central Subway to high-platform service. More important is the future of the Beacon and/or Commonwealth Avenue streetcar service which could logically be converted to feeder bus service if the volumes on these lines actually decay to the predicted 1990 levels. A detailed inspection of these forecasts indicates that approximately 1,700 riders boarding the Riverside Line between Reservoir and Fenway Park have closer access to the Beacon Street Line, while approximately 1,900 riders assigned to the Riverside Line have closer access to the Commonwealth Avenue Line. However, the traffic assignments are based on line haul time (and cost) and access time (and cost) at the destination end of the trip, as well as access time (and cost) from origin to boarding station. Thus, although it appears more likely that passengers would board the nearest transit station or streetcar stop, the traffic forecasts reflect the times and costs involved in the total trip from origin to destination. If one chooses not to believe the consultant forecasts which show a large diversion of riders from Beacon and Commonwealth to the Riverside Line, then the ridership loss, indicated in Chapter 9 for Downtown Systems 3 and 4 due to the required transfer from Beacon and Commonwealth to Riverside, is underestimated since approximately 14,000 inbound riders on the Beacon and Commonwealth Lines combined rather than 10,000 would be affected by the transfer. Systems 3 and 4 would then be even less favorable compared with Systems 1 and 2 than indicated in Chapter 9.

The merits of extending the Riverside Line beyond the existing Riverside Station terminal can be evaluated by considering the changes in station boardings west of Reservoir Station where the Beacon and Commonwealth Lines do not compete with the Riverside Line. This avoids the dilemma of whether to accept the diversion of Beacon-Commonwealth riders to the upgraded Riverside Line. Also, inbound station boardings east of Chestnut Hill are not affected by an extension beyond Riverside. Table 3-2 includes the inbound station boardings west of Reservoir Station for Alternatives 1, 2 and 3 during the 7-10 A.M. peak period. The 24-hour station boardings for Alternative 1 are also shown; however, 24-hour station boardings were not produced for Alternatives 2 and 3. Also included in this table are the parking space demands at each station which are shown in parentheses. Comparison between 1990 Alternatives 1 and 2 (or 3) indicates that the extension from Riverside to Framingham increases the total station boardings by only 1% (12,587 to 12,707) even though 33% or 4,157 boardings in the peak period occur at

Table 3-2

1990 - Inbound Station Boardings - (Parking Space Demand)

	7-10 A.M.		24-Hour			
	Alternative 1	Alternatives 2,3	Alternative 1	Alt.2,3	Alt.5	1970*
Framingham	-	1,247 (478)	-	Not Produced	-	-
Speen Street	-	550 (208)	-		-	-
Natick MB	-	1,291 (382)	-		-	-
Wellesley	-	298 (65)	-		-	-
Wellesley Hills	-	425 (73)	-		-	-
Wellesley Farms	-	346 (92)	-		-	-
Riverside	5,704 (3,701)	3,697 (2,210)	12,074 (7,385)		6,200	2,300
Woodland	2,325 (1,092)	295 (61)	5,294 (2,113)		1,780	970
Waban	450 (87)	450 (89)	1,026 (204)		1,065	540
Eliot	-	-	-		720	450
Newton Highlands	1,026 (308)	1,026 (319)	2,761 (810)		1,430	955
Newton Center	1,817 (451)	1,817 (446)	4,499 (1,005)		2,270	2,060
Chestnut Hill	1,265 (496)	1,265 (496)	3,193 (1,036)		1,280	730
Total	12,587 (6,135)	12,707 (4,919)	28,847 (12,553)		14,745	8,005

4,157 boardings west of Riverside = 33% of total boardings west of Reservoir.
51% of total boardings west of Waban.

2,250 parking spaces currently available between Riverside and Chestnut Hill.

1,300 parking space demand in A.M. peak period west of Riverside.
2,600 parking space demand in 24-hour period west of Riverside.

*1970 station boarding volumes include two-way boardings; long-range forecasts include inbound boardings only.

This study assumed elimination of Eliot Station because of low volume.

stations west of Riverside. Analyses indicate that the extension to Framingham does not produce any appreciable net increase in modal splits (percent transit ridership) for the suburban zones in the Western Corridor. Transit ridership increased 5% in the Wellesley, Natick and South Framingham area, while transit ridership declined by 3% to 4% in North Framingham and to the northwest due to substitution of the rapid transit extension for express bus service to Riverside. Comparison of the individual station boardings indicates that station boardings east of Woodland Station are unaffected by the Framingham extension. Thus, the 4,157 peak period boardings west of Riverside Station represent 50% of the total station boardings which are affected by the extension, and it could be concluded that the extension provides improved service for approximately 4,000 peak period or 8,000 daily inbound transit riders with only a slight net effect on overall ridership demand. This conclusion is extremely misleading unless it is qualified with the stipulation that the parking demand can be satisfied under each alternative.

Alternative 1 produces a demand for 7,400 spaces at Riverside and 12,550 spaces for the line west of Reservoir. It is unlikely that this parking space demand can be satisfied without extending the line beyond Riverside considering there are now only 1,600 spaces at Riverside and 2,250 spaces between Riverside and Chestnut Hill. Thus, the extension beyond Riverside would produce increases in line ridership by providing parking space supply to satisfy the enormous parking demand. Assuming that the parking space supply at Chestnut Hill, Newton Center, Newton Highlands and Woodland can be expanded from the present small parking lots, which range in size from 50 to 350 spaces, to 1000-2000 car lots and that Riverside parking can be practically expanded to a 3,000 car lot or parking structure, there would still remain an unsatisfied demand for approximately 4,500 spaces which may be reasonably satisfied by extending the line beyond Riverside. However, examination of the parking demand between Alternatives 1 and 2 (or 3) indicates that the extension to Framingham reduces the peak period parking demand from 6,135 to 4,920, or 20%, due to the increased choice of station access modes available with the extension (i.e., easier station access for walk-in, kiss-ride and bus passengers). Thus, the extension to Framingham would reduce the daily parking demand from 12,550 spaces, which is concentrated at Riverside and Woodland Stations for Alternative 1 to approximately 10,000 parking spaces which, although still somewhat concentrated at Riverside, are more evenly distributed from Woodland to Framingham.

The unsatisfied demand for approximately 4,500 parking spaces in Alternative 1 represents a potential loss of 5,000 to 5,800 daily inbound transit passengers or $1.5 to $1.74 million (1970 dollars) in fare box revenue annually.* Stated another way, the extension to Framingham (Alternatives 2 and 3) would provide the facilities (station access and parking capacity) to meet the unsatisfied demand in Alternative 1 and would produce between $1.5 and $1.74 million additional annual revenue.

Analysis of Alternative 3 was made to determine the effect of routing the Riverside Line, from Brookline Village to Huntington Avenue, on inbound boardings at stations affected by the rerouting and also on inbound trips destined for the areas directly influenced by the new route.

Alternative 3 differs from Alternative 2 in that the inner segment of the Riverside Line is shifted from Kenmore Square to Huntington Avenue with additional adjustments in the feeder bus and Green Line networks. The model output for the 7-10 A.M. peak period indicates a loss in boardings from zones in the Kenmore Square-Longwood Avenue area of 200 or 12%, and a comparable gain of 150 or 10% from zones along Huntington Avenue. The loss in boardings from zones in the Kenmore-Longwood area result from replacing the high-platform Riverside Line service from Brookline Village, to and through downtown in Alternative 2, with a low-platform trolley service from Brookline Village through the Central Subway to North Station in Alternative 3. Similarly, the gain in ridership along Huntington Avenue reflects the increased speeds, improved downtown distribution and through downtown service afforded by the rerouted high-platform Riverside Line along Huntington Avenue in Alternative 3, which replaces the low-platform trolley service along Huntington Avenue and through the Central Subway to North Station in Alternative 2.

An additional and more significant effect on boardings is an increase of 850 trips at Brookline Village Station which originate from Jamaica Plain; 650 of these trips are diverted from the Orange Line due to realignment of bus routes in Alternative 3.

The effect of the rerouting on trips destined for the area affected by the rerouting is more significant. The traffic model was applied to origin zones in Newton (which had the

*Conservatively based on a 50¢ one-way fare.

same sub-modal splits for both Alternatives 1 and 3) in order to analyze these effects. The changes in ridership by destination due to the Riverside-Huntington alignment are shown in Table 3-3. The affected alightment stations along the existing Riverside Line (i.e., Auditorium, Kenmore, Longwood) experience 16%-26% reduction in alightments due to the new Riverside Line alignment, while stations along the rerouted line (i.e., Prudential, Northeastern, Brigham Circle) experience 7%-98% increase in alightments due to the new alignment. However, the net effect of the new alignment is to reduce station alightments by 4%.

The main effect of the new Riverside Line alignment (Alternative 3) for trips originating in Brookline and Brighton is a diversion of riders to the Green Lines for destinations in the Back Bay and Kenmore Square area.

The effect of rerouting the Riverside Line via Huntington Avenue thus does not produce significant net changes in transit ridership which would justify the high capital costs of Alternative 3 compared with Alternative 2 in terms of system changes east of Brookline Village.

Comparison of Alternative 5 (1990-C) with current ridership for stations west of Reservoir (see Table 3-2) shows a projected ridership increase of 85% over the 20-year period even without major improvements in the Riverside Line beyond expansion of park-ride facilities. Comparison of Alternative 5 with Alternative 1 indicates the impact of converting the Riverside Line to high-platform service, diverting it out of the Central Subway and through routing it to the Blue Line. Alternative 1 also includes express feeder bus service to Riverside which is not included in Alternative 5. Alternative 5 also includes 2,300 inbound trips on the Penn Central Railroad, which should be added to the Riverside Line boardings for comparison of Alternative 5 with Alternative 1. Thus, it may be concluded that upgrading the Riverside Line in Alternative 1 would increase ridership west of Reservoir by 70% in 1990 (from 17,000 to 29,000) primarily at the outer stations.

Table 3-4 gives 1990 24-hour station boardings for the Riverside Line to the Central Subway for several alternatives compared to 1970 counts.

Table 3-3

EFFECTS OF RIVERSIDE-HUNTINGTON AVENUE ALIGNMENT

Alightments at Destinations for Peak Period Trips Originating in Newton

Destination	Kenmore Alignment Alternative 2	Huntington Alignment Alternative 3	% Change
Western Back Bay (Auditorium)	222	175	-21%
Prudential	277	296	+7%
Kenmore	552	463	-16%
Longwood (Highland Branch)	372	276	-26%
Northeastern	97	192	+98%
Brigham Circle	229	364	+59%
Cambridge (Mass. Ave. Bus)	577	460	-15%
Totals	2,326	2,226	-4%

COMPARISON OF RIVERSIDE LINE BOARDINGS FOR
THE PRESENT SYSTEM AND CERTAIN ALTERNATIVES

		1990 Daily Inbound Station Boardings (24-Hour)			
	1970	Alt. 1	Alt. 4 1990-Rec.	Alt. 5 1990-C	Alt. 6 1990-A
Framingham	-	-	-	-	-
Speen Street	-	-	-	-	-
Natick Middle Belt	-	-	7,225	-	-
Wellesley	-	-	729	-	-
Wellesley Hills	-	-	1,337	-	-
Wellesley Farms	-	-	-	-	-
Riverside	2,300	12,074	12,789	6,200	550
Woodland	970	5,294	-	1,780	274
Waban	540	1,026	1,606	1,605	915
Eliot	-	-	-	540	-
Newton Highlands	955	2,761	2,965	1,430	1,800
Newton Centre	2,060	4,499	3,752	2,270	1,584
Chestnut Hill	730	3,193	2,838	1,280	1,111
Reservoir	1,330	6,461	7,473	1,283	774
Beaconsfield	375	-	-	469	414
Brookline Hills	1,665	2,333	2,306	1,521	1,530
Brookline Village	2,030	3,469	5,438	1,398	1,245
Longwood	1,160	1,339	-	462	448
Fenway	2,690	3,369*	4,062*	3,048	2,925
TOTAL BOARDINGS	16,805	45,818	52,520	22,206	13,570

*In Alternatives 1 and 4, Fenway Station is located closer to existing Kenmore Station and connected to Kenmore with free transfer.

Notes

1970 boarding counts include both inbound and outbound boardings. 1970 inbound line volumes include trips originating in Western Corridor and other corridors.

Future year forecasts do not include outbound boardings or trips originating from other corridors.

Eliot Station omitted because of low projected volume.

An analysis of projected operating costs for the Western Corridor indicated an annual operating cost for the through route from Riverside to Wonderland of $15,994,148. Extending the Riverside Line to Natick would increase operating costs by $4,442,427 to a total of $20,436,575. Extending further to Framingham would increase operating costs another $757,475 to a total of $21,194,050. These costs were based on assumed peak hour headways of 5 minutes between Framingham and Riverside, and 2-1/2 minutes from Riverside to Wonderland.

DeLeuw, Cather & Company, the Engineering Consultants, estimated the construction cost of a rapid transit extension from Riverside to Framingham at $36,974,000. They also estimated that conversion of the Penn Central (B&A) main line between Fenway Park and Riverside to rapid transit would cost $24,575,000, assuming that railroad freight operations could be discontinued. These estimates were based on heavy rapid transit standards. Less costly schemes would be possible. See Chapters 6 and 7 of Volume II.

ALTERNATIVE GREEN LINE EXTENSION TO NEEDHAM

Budget limitations prevented comprehensive testing of a suggested extension from Cook's Junction to Needham as part of one of the alternatives for improved rail service in the Western Corridor. The objective was to determine whether a branch from the Green Line at Cook's Junction into Needham was feasible, and whether it would be a better way to serve Needham by rail than the proposed Orange Line extension into Needham via West Roxbury.

The available traffic data for the Needham area was studied in some detail, and comparisons were made between the existing commuter railroad ridership and forecasts which were made in a 1966 corridor traffic study. These forecasts indicated the expected railroad and rail transit ridership from Needham after the opening of the Orange Line Southwest Extension as proposed in the Authority's Program for Mass Transportation. This forecast assumed completion of the Orange Line extension as far as the V.F.W. Parkway in West Roxbury, with Railroad shuttle service between there and Needham Heights.

Under the above alternative, the trunk line time from Needham Heights Station to Downtown Boston would be 32 minutes, compared with the existing 36 minutes on the present Needham Branch railroad service. The trunk line times from the remaining Needham stations would also be less than existing railroad times due to the performance advantages of rapid transit service. It was estimated that approximately 1,900 rail transit riders would originate from Needham as shown on the following station assignment summary:

Estimated Rail-Transit Trips Originating from Needham

Station (or Line)	Walk	Kiss-Ride	Park-Ride	Total
Needham Heights	149	176	10	335
Needham	240	172	0	412
Needham Junction	35	17	34	86
Bird's Hill	166	154	70	390
VFW - Rapid Transit	0	79	290	369
Riverside Line	0	230	59	289
Totals	590	828	463	1,881

The following 1969 railroad passenger origin-destination survey data, taken from a one-day count, shows the actual Needham boardings for the existing railroad service:

					Total Boardings	
Station	Walk	Kiss-Ride	Park-Ride	Parking Spaces	All Origins	From Needham
Needham Heights	57	10	10	15	77	74
Needham	99	36	28	120	162	153
Needham Junction	76	76	167	110	319	202
Bird's Hill	107	130	81	100	318	271
Totals	339	252	286	345	876	700

The average weekday boardings at the Needham stations is 900, which includes passengers originating from Needham and other towns. Approximately 80%-85% of the passengers boarding at the Needham stations are Needham residents. The relative convenience of the four Needham railroad stations is apparent by the high proportion of walk-in traffic which accounts for between 50%-60% of the station boardings by Needham residents. The park-ride facilities are underutilized at the Needham Station which attracts a high proportion of walk-in traffic.

In addition to the commuter railroad trips indicated above, there are approximately 420 trips from Needham which use the Riverside car line and another 35 trips made via MBTA express bus from Riverside over the Massachusetts Turnpike which has a 23-minute trunk line time to Downtown Boston.

The following table illustrates the distribution of trips among the five traffic analysis zones in Needham. Current transit trips to Downtown Boston from Needham are mainly generated by Zones 152 and 154 which exhibit 67% and 77% transit trips, respectively.

Origin Zone	Trips to Downtown Boston		Trips to All Destinations	
in Needham	Transit	Total Person	Transit	Total Person
150	0	17	163	8,900
151	107	333	195	9,619
152	750	1,167	1,128	32,850
153	68	408	102	6,316
154	459	598	564	10,517
Totals	1,384	2,523	2,152	68,202

(Source: Boston Regional Planning Project - Home Interview Survey)

Zone 152 is bounded by the four Needham railroad stations which accounts for the high proportion of transit trips to Downtown Boston. Zone 154 is convenient to Needham and Needham Junction stations and produces the highest generation of transit trips to Downtown from Needham. Zone 153, which is bounded by the railroad on the North, the Charles River on the South, and Route 128 on the East, has a surprisingly low generation rate of transit trips to Downtown Boston (only 17%) considering the proximity to Needham Junction and Bird's Hill stations. Zone 150 in the Northeast corner of Needham would be well served by a Green Line extension, assuming a new station would be located at Newton Upper Falls which is near the centroid of this Zone. However, this Zone had no reported transit trips to Downtown Boston in 1963, and only 17 total person trips to Downtown Boston, compared with Zone 152 which generated 750 transit trips and 1,167 total person trips to Downtown Boston.

The above data illustrates that the present railroad service is capturing about 55% of the total person trips to Downtown Boston, which is a high percentage. It also shows that the service serves mainly a local Needham market with a high proportion of walk-ins, and not a very large market.

The engineering consultant has estimated that it would cost $14,352,000 to build a rail rapid transit extension from Cook's Junction to Needham Heights, a distance of 12,400 feet, but $38,122,000 from Needham Heights to Needham Junction, a distance

of only 7,500 feet. Extending beyond Needham Heights, therefore, would be completely out of the question, especially in view of the parking and highway access problems in this built-up area.

If a Green Line extension were built to Needham Heights, the trunk line travel time from Needham Heights to Downtown Boston would be about the same as the present railroad service assuming improvements to the Riverside Line. The fare would undoubtedly be lower and the service more frequent. However, the convenient walk access to the Needham, Needham Junction, and Bird's Hill stations would be eliminated. Passengers would have to use auto access to Needham Heights Station. Parking facilities at Needham Heights would be quite limited due to the lack of available land. For this extension to be successful, it would have to provide easy access and ample parking near Route 128. This would be very difficult.

The proposed Orange Line extension will not be able to serve the center of Needham, either, but the access problems from Needham would be simpler, and a major parking facility could be provided at Route 128.

Another major disadvantage of a Green Line extension to Needham Heights would be the necessary reduction in the frequency of service between Eliot and Riverside Stations. This service would be diverted to the Needham Branch to avoid over-servicing the trunk line by superimposing new Needham Branch service on the existing level of Highland Branch service. A reduction in service frequency between Riverside and Eliot would result in some ridership loss depending on the magnitude of this change. Assuming an extreme increase in headways from the present 5 minutes to 10 minutes in the peak period between Riverside and Eliot Stations, the excess time would be increased by 2.5 minutes and produce an estimated 10% ridership loss (3.9% change per minute of excess time), which would amount to a loss of approximately 400 inbound transit trips between Riverside and Eliot Stations.

Needham Branch service could also add congestion and confusion in the Central Subway operation by increasing the number of trains with different destinations in the outbound direction. The Central Subway already suffers from having too many different lines operating through a single stretch of subway.

CONCLUSIONS AND RECOMMENDATIONS FOR WESTERN CORRIDOR SYSTEM CHANGES

The Western Corridor alternatives which were tested and analyzed during the course of this study did not produce any significant net change in the modal splits (percent transit ridership) and resulting total ridership demand when compared with each other. However, the inability of Alternative 1 to meet the projected park-ride demands and the ability of an extension beyond Riverside (Alternatives 2 and 3) to reduce the overall park-ride demand and satisfy the projected transit demand indicates the need to extend rapid transit somewhere beyond the Riverside terminal. The extremely high operating and capital costs associated with an extension all the way to Framingham compared with the relatively modest increase in transit revenue which this extension would produce obviates the feasibility of such an extension based on this comparison alone. There are of course numerous benefits associated with an extension to Framingham which have not been identified or quantified in this study (e.g., reduction in highway investments and road user costs, increases in land development and general economic growth). This study has indicated however that a more limited (and therefore less expensive) extension beyond Riverside could attract and accommodate an equal number of transit riders (although not the same transit riders) as an extension to Framingham; and that without an extension beyond Riverside there would be a loss of 5,000-6,000 potential transit riders due to parking capacity constraints.

All alternatives indicate the need to expand parking capacities and improve auto access to Riverside, Newton Highlands, Newton Center and Chestnut Hill Stations. Alternative 1 indicates an even greater need to expand parking at Riverside and in addition Woodland Station.

A rapid transit extension to Framingham generates only moderate station boarding volumes at Framingham and the Natick Middle Belt, while the station boarding volumes at Speen Street, Wellesley, Wellesley Hills and Wellesley Farms are below levels sufficient to support rapid transit service. This further demonstrates the lack of justification for such extensive rapid transit service beyond Riverside.

Rerouting the Highland Branch via Huntington Avenue (Alternative 3) does not produce significant net ridership benefits to justify the added costs of this alternative, as compared to Alternatives 1, 2 and 4.

The results of this study indicate a great need for upgrading the Riverside Line to high-platform service to accommodate future suburban growth in the Western Corridor which, together with improved transit service levels and an increased number of core-oriented trips, will generate approximately 20,000 additional inbound station boardings on the Riverside Line at stations west of Reservoir. This represents a 360% increase in station boardings west of Reservoir between 1970 and 1990. Parking space demand west of Reservoir will increase by 8,000 to 10,000 spaces in addition to those currently available. This amounts to a 450%-550% increase in parking space demand. Thus, the new demand on the Riverside Line will become heavily concentrated with park-riders which will require substantial new and improved access and parking facilities.

The technical problems of achieving a high-platform service for the Riverside Line are discussed in later chapters. Although Alternative 3 shows no marked advantage over the other alternatives, which call for conversion to high platforms, it is the only one studied which neither requires the use of the Boston & Albany right-of-way, nor the destruction of the single-ride, surface-subway service on Commonwealth Avenue and Beacon Street. If conversion to high platforms ever becomes a necessity, then Alternative 3 may prove to be the most desirable despite its high cost.

Construction of a Green Line extension from Cook's Junction to Needham Heights would be less desirable for serving the Needham area than the Orange Line extension via West Roxbury. A good feeder bus network could provide good service for Needham residents to the Orange Line terminal at Route 128 and/or to the Riverside Line.

If it is determined that the Orange Line extension cannot be built for some reason, then consideration should again be given to a Green Line extension to Needham Heights. It may be that a less expensive mode than conventional rapid transit could be constructed, with transfer facilities at Cook's Junction. For example, the right-of-way could be paved over for use as an exclusive busway.

If it should become necessary to discontinue the existing railroad service before the Riverside Line can be improved or the Orange Line extension built, a good low-cost solution might be the provision of an express bus service from Needham to Downtown Boston via the Massachusetts Turnpike.

CHAPTER 4

ALTERNATIVES EVALUATED FOR THE NORTHEAST CORRIDOR STUDY

DESCRIPTION OF NORTHEAST CORRIDOR ALTERNATIVES

Alternative 1

The Blue Line is extended from the existing terminal at Wonderland Station to a new terminal at Pines River in Revere. The downtown end of the line at Bowdoin Station is extended to Park Street and forms a through connection to the Riverside Line. The downtown system configuration is the same as that for Downtown System 1 in Chapter 9. The B&M rail passenger service terminates at the Pines River Station with transfer to the Blue Line.

Alternative 2

This alternative is identical to Alternative 1 except that an express track service is added between the Pines River Station terminal and Airport Transit Station.

Alternative 3

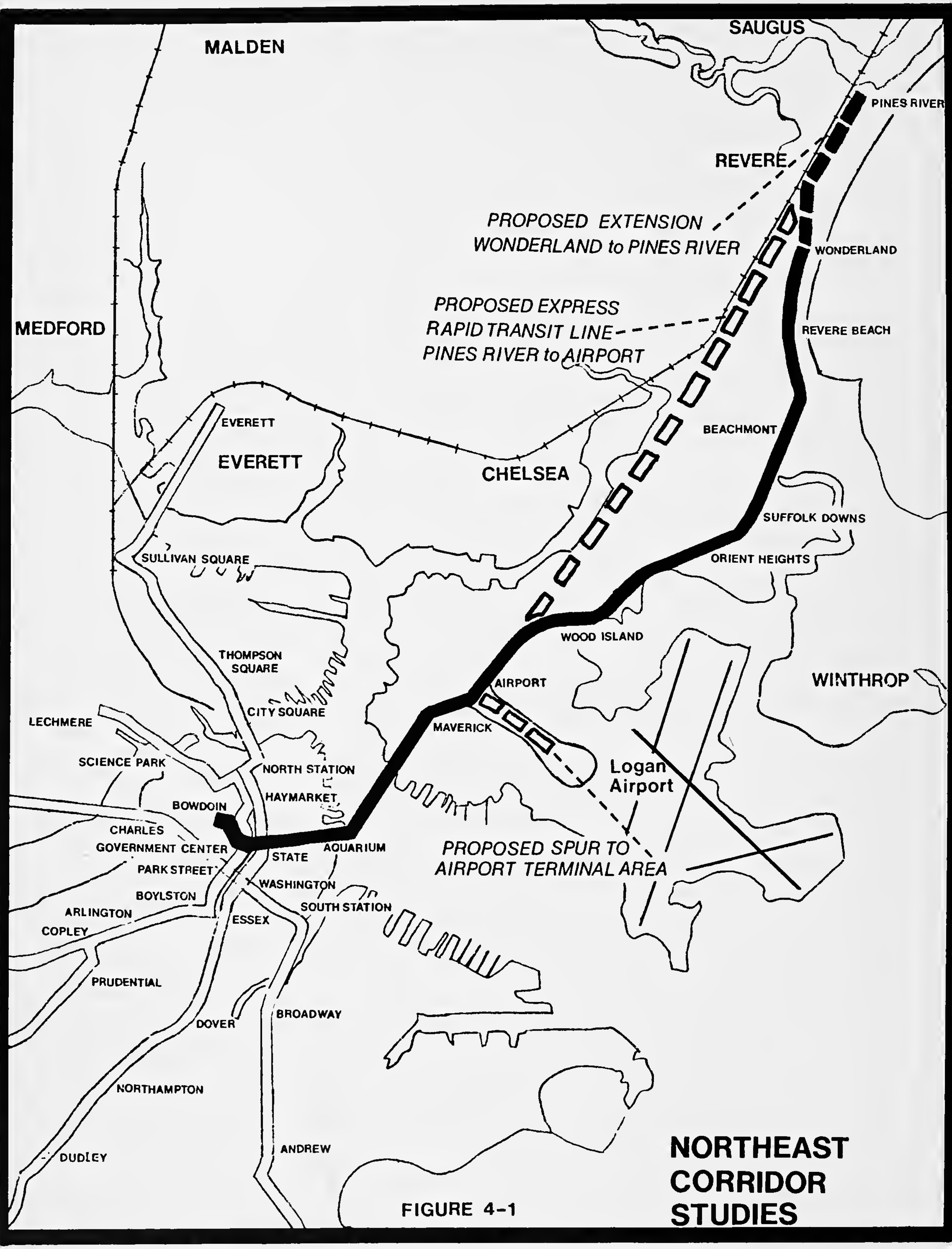
This alternative is identical to Alternative 1 except that B&M shuttle railroad passenger service to Pines River terminal is replaced by express bus service to Pines River Station.

Alternative 4

This alternative is identical to Alternative 1 except that B&M shuttle railroad passenger service to Pines River terminal is replaced by express bus service to Pines River Station (as in Alternative 3) and an express track is added between the Pines River terminal and Airport Transit Station (as in Alternative 2).

Alternative 5

This alternative represents the recommended long-range Northeast Corridor configuration described in the "Recommended Highway and Transit Plan" Report. The Blue Line is extended to Tedesco in Salem with stations at Swampscott, Lynn and Pines River. An express rapid transit track is added between Pines River Station



SAUGUS
MALDEN
PINES RIVER
REVERE
PROPOSED EXTENSION
WONDERLAND to PINES RIVER
WONDERLAND
PROPOSED EXPRESS
RAPID TRANSIT LINE
PINES RIVER to AIRPORT
MEDFORD
REVERE BEACH
EVERETT
BEACHMONT
EVERETT
CHELSEA
SUFFOLK DOWNS
SULLIVAN SQUARE
ORIENT HEIGHTS
WOOD ISLAND
THOMPSON
SQUARE
WINTHROP
AIRPORT
CITY SQUARE
LECHMERE
MAVERICK
SCIENCE PARK
Logan
Airport
NORTH STATION
HAYMARKET
BOWDOIN
CHARLES
GOVERNMENT CENTER
AQUARIUM
PROPOSED SPUR TO
AIRPORT TERMINAL AREA
STATE
PARK STREET
WASHINGTON
BOYLSTON
SOUTH STATION
ARLINGTON
ESSEX
COPLEY
PRUDENTIAL
BROADWAY
DOVER
NORTHAMPTON
ANDREW
DUDLEY
NORTHEAST
CORRIDOR
STUDIES

FIGURE 4-1

and Airport Transit Station. This alternative also includes a loop track into Logan Terminal from Wood Island Station and a through downtown connection to the rerouted Riverside Line. The downtown system configuration is the same as that for System 1 in Chapter 9. The forecasts for this alternative were developed outside the CASS scope.

Alternative 6

This alternative is referred to in the "Recommended Highway and Transit Plan" Report as the Northeast Corridor portion of the 1990 "Plan C" network. The Blue Line remains as today without any line extension or new route alignment. Conventional rail passenger service is maintained over the B&M Eastern Route between North Beverly and North Station. Changes in the Blue Line service are in the form of new rolling stock. The forecasts for this system were made several years ago prior to the CASS Project and are included for comparison purposes.

Alternative 7

This alternative is referred to in the "Recommended Highway and Transit Plan" Report as the Northeast Corridor portion of the 1990 "Plan A" network. The Blue Line is extended from Wonderland Station to Route 128 in North Beverly. An express track is added between the Revere Marshes and Airport Transit Station. The downtown end of the Blue Line is extended from Bowdoin to Lechmere. The forecasts for this system were also made prior to CASS and are included for comparison purposes.

COMPARATIVE ANALYSIS OF NORTHEAST CORRIDOR ALTERNATIVES

Traffic analysis results of the Northeast Corridor are less controversial than the Western Corridor due to the absence of competing rail lines which raised the question of trip assignments to various lines in the Western Corridor. The Northeast Corridor analysis concentrates on determining the need for an extension beyond the present terminal at Wonderland and also the need for express track service from a new terminal at Pines River to Airport Station. A third question, for which there was a limited data base, concerns the need for direct rail service into the Airport terminal complex from either the Downtown or North Shore end of the Blue Line.

Comparison of Alternatives 1 to 4 (see Table 4-1) indicates only small differences in total station boardings. Alternative 2,

with 43,982 inbound boardings, attracts the highest ridership of the four alternatives; this is an all-rail system including an extension to Pines River with feeder rail service to Pines River and express rapid transit from Pines River to Airport Station. Alternative 3 with 40,719 inbound boardings attracts the lowest ridership volume; this alternative is the least costly and includes an extension to Pines River with express bus service feeding Pines River from Peabody, Manchester and Salem.

Alternative 6 (1990-C) which was developed prior to CASS shows total inbound boardings of 31,330 with no extension beyond Wonderland, with conventional railroad service into North Station, and no downtown extension from Bowdoin Station (see Table 4-2). This alternative is not directly comparable to Alternative 1 for evaluating the ridership impact of extending rapid transit to Pines River since all of the four CASS Alternatives 1 to 4 include a through connection from Bowdoin to Park Station. In addition, Alternative 1 suburban railroad service terminates at Pines River, while Alternative 6 railroad service continues to North Station. However, by combining the 31,330 rapid transit boardings in Alternative 6 with the estimated 5,225 railroad boardings (which are not shown in Table 4-2) produces 36,555 inbound rail trips for Alternative 6 compared with 43,277 for Alternative 1. Thus, it may be concluded the extension to Pines River in conjunction with the downtown extension between Bowdoin and Park produces approximately 6,700 additional inbound boardings in 1990.

Comparing the existing (1970) Blue Line boardings of approximately 23,000 with the 1990 estimates of 31,000 for the same system (Alternative 6), shows a 35% increase over the 20-year period. However, by extending the Blue Line to Pines River, connecting the downtown end to the Green Line, and feeding the commuter rail trips into Pines River, the projected growth is 87% (23,000 to 43,000). The major part of this growth is due to the Pines River extension and railroad feeder service to Pines River Station coupled with corridor trip growth since the downtown connection alone increases inbound boardings by less than 1,000 for the 1990 forecasts. This conclusion is further confirmed by the high volume boardings at Pines River Terminal (see Alternatives 1 and 3).

Table 4-1

NORTH SHORE SUMMARY

Inbound Station Boardings

	Peak Period (7-10 A.M.)	24-Hour
1970 (Existing)	9,600	22,910
Alternative		
1	18,332	43,277
2	18,673	43,982
3	17,652	40,719
4	18,013	42,858
5 (1990 Rec.)	19,203	Not Comparable

Table 4-2

BLUE LINE INBOUND DAILY BOARDINGS

	1970	Alt. 1	Alt. 2	Alt. 3	Alt. 4	1990-C Alt. 6	1990-A Alt. 7	1990 Rec. Alt. 5
Rt. 128 Beverly	-	-	-	-	-	-	4,199	-
Beverly	-	-	-	-	-	-	1,118	-
Salem	-	-	-	-	-	-	1,401	-
Tedesco	-	-	-	-	-	-	1,912	7,410
Swampscott	-	-	-	-	-	-	741	2,456
Lynn	-	-	Not Produced	-	Not Produced	-	3,117	4,886
Pines River Express	-	-		-		-	3,729	6,887
Pines River Local	-	17,538		14,967		-	-	508
Wonderland	3,670	2,540		2,539		6,937	2,294	-
Revere Beach	1,740	1,884		1,885		2,342	2,028	3,325
Beachmont	1,690	3,177		3,190		1,601	1,334	3,461
Suffolk Downs	895	408		408		297	269	-
Orient Heights	4,175	5,902		5,902		5,543	5,492	6,328
Wood Island	3,150	2,705		2,705		5,417	4,520	2,658
Airport	2,150	6,928		6,928		1,650	1,468	4,107
Maverick	5,440	2,195		2,195		7,543	7,347	4,071
Logan	-	-		-		-	-	7,816*
Total	22,910	43,277	43,982	40,719	42,858	31,330	40,969	53,913

*The 7,816 boardings at Logan Station include trips to all external destinations and thus are not limited to inbound boardings as indicated in the Table Heading.

Comparison of Alternative 3 (local service to Pines River) with Alternative 5 (extension to Tedesco in Salem, See Table 4-1) indicates that the rapid transit extension to Salem, together with the express line from Pines River to Airport and a rail loop into Logan, increases peak period riding by nearly 1,600 trips for approximately 9% increase in the total system. Approximately 25% of this increase is due to the express service alone, while the remaining 75% is due to a combination of the express service from Pines River to Airport, the extension, and loop service into Logan.

The express rapid transit service, coupled with the B&M railroad feeder service to Pines River (Alternative 2) produces no significant change in system ridership when compared with Alternative 1 (no express service).

Comparison of Alternative 2 (extension to Pines River plus express track) with Alternative 5 (extension to Tedesco, Salem, plus express track, plus loop into Logan) in Table 4-2, shows a gain of 10,000 riders or nearly a 25% increase with the extension to Salem. Close inspection of Table 4-2 shows that 7,800 of these 10,000 additional riders board at Logan in Alternative 5, while Airport Station boardings drop from approximately 7,000 in Alternative 1 to approximately 4,000 in Alternative 5. Thus, the Logan loop accounts for approximately 5,000 /i.e., (7816 + 4107)-6928/ of the 10,000 additional boardings and the remaining 5,000 are due to the Salem extension. It should be noted here that the 7,800 boardings at Logan Station in Alternative 5 include trips from the Airport to all external destinations and are not limited to inbound directional boardings. The loop service into the Logan air terminal thus is estimated to attract 7,816 boardings of which approximately 2,800 would use the Airport Station in the absence of the Logan rail loop service.

THE ENGINEERING CONSULTANT'S FINDINGS

Volume IV of this Report contains the engineering feasibility study and recommendations of the engineering consultant, Colonel S. H. Bingham Associates, Inc. regarding the Blue Line proposals.

The engineering consultant studied four steps, or "phases" for Blue Line improvements:

Phase I: Included the extension from Wonderland to the Pines River area.

Phase II: Added a two-track express line from the Pines River Terminal to a connection with the existing Blue Line just north of Airport Station.

Phase III: Covered a two-track subway spur from the Blue Line north of Maverick Station to a new Logan Terminal Station near the present parking garage.

Phase IV: Covered connecting the express track to the Logan spur instead of to the main Blue Line, so as to provide direct access to Logan from the north.

The consultant found that constructing a "loop" track at Logan would be impossible, and a stub-ended spur would be the only feasible way of bringing rail transit closer to the Airline Terminal area. Furthermore, such a spur would have to be in subway because of limited available land and conflict with access roads.

The consultant recommended construction of the extension to Pines River (Phase I). He recommended against construction of the express line, primarily because it represented less than a five-minute saving in running time. The traffic analysis confirms this recommendation.

The engineering consultant estimated that construction of the Pines River extension would cost $28,650,000, the express line $48,720,000, and the spur to Logan Airport Terminal $26,050,000. These costs do not include the costs of railroad right-of-way, acquisition of property, or of new cars.

Phase IV, express track connection to the Airport spur, cannot exist without Phase II, the express track. The combined cost of Phase II and Phase IV would be $63,520,000.

The consultant recommended in favor of constructing Phase I and Phase III, but against Phase II and Phase IV. The Authority staff agrees with the Phase I recommendation with certain reservations, and disagrees with the Phase III recommendation. The staff agrees that Phases II and IV should not be built.

OPERATING COSTS

An analysis of projected operating costs for the various phases of the proposed Blue Line improvements was carried out. The results are shown in Table 4-3.

NORTHEAST CORRIDOR - PROJECTED OPERATING COSTS

	Peak-Hour Headway (Minutes)	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Present Operation				
Routes: Wonderland to Bowdoin Orient Heights to Bowdoin	2.5	$6,453,289	2,704,081	56
Extension to Pines River (Phase I)				
Routes: Pines River to Bowdoin (Local Only) Orient Heights to Bowdoin	2.5	$6,679,633	3,012,100	60
Extension to Pines River (Phase II)				
Routes: Pines River to Bowdoin (Local and Express) Orient Heights to Bowdoin	2.5	$6,722,859	3,035,151	72
Extension to Pines River and Airport (Phase III)				
Routes: Pines River to Bowdoin (Local and Express) Orient Heights to Bowdoin New Airport Station to Bowdoin	2.5	$6,309,207	2,990,004	68

It is interesting to note that the operating cost for Phase III, which includes the spur track to Logan Airport, would cost less to operate than either Phase I or Phase II. The reason for this is that in order to maintain 2.5 minute headways on the downtown end of the line, the headways north of Maverick Station would have to be increased on the main leg of the Blue Line, resulting in a poorer level of service for those riders.

LOGAN AIRPORT TRAVEL SURVEY

The MBTA is participating in a study of ground travel to and from Logan International Airport, which is receiving Federal aid in the form of a Technical Study Grant from the Urban Mass Transportation Administration. The project is under the direction of the Massachusetts Department of Public Works, Bureau of Transportation Planning and Development. The other participants are the Massachusetts Port Authority, the Massachusetts Turnpike Authority, the City of Boston, and the MBTA.

One of the objectives of the Logan Airport Travel Survey is to determine what type of improvements to public transportation service and how much service in comparison to other modes will best meet the needs of Airport users.

Personal interviews were conducted at Logan Airport in June 1970, but final results are not expected to be available before February or March of 1971. However, some of the data has now been processed and some preliminary results are beginning to appear. These results have a bearing on the need for the Blue and Green Line improvements that were studied under the CASS Project.

Several separate sets of interviews were conducted. These included enplaning passengers, deplaning passengers, visitors, Airport employees, shuttle bus patrons. Data was gathered relative to origins and destinations, age, sex, occupation, trip purpose, baggage, and attitude towards available ground transportation.

Some preliminary results of the attitudinal survey are now available and are discussed below. Approximately 600 attitudinal survey interviews were conducted, which represents 0.7% of the average number of weekday person trips to and from Logan (87,000). The survey was conducted at various locations throughout the Airport complex, but was mainly concentrated on the shuttle bus.

The primary purpose of the attitudinal survey was to determine attitudes of the ground travel market towards:

- existing transit services,
- proposed improvements to existing transit services,
- proposed new transit services.

Preferences for New Transit Services

Attitudes toward four proposed new transit services were solicited by asking the respondent to indicate his first, second and third preference for the four hypothetical improvements. These new services represent solutions to basic weaknesses in the present transit system service to Logan:

1. Downtown transfers are required between Red and Blue and Green and Blue Lines. Two transfers are now required between the Red and Blue Lines which would be reduced to one transfer if part of the Green Line were extended from Park Station to Bowdoin Station providing through service from the Western Corridor to the East Boston Corridor, thus eliminating the one transfer now required between the Green and Blue Lines.

2. Rapid transit passengers now must transfer between the Blue Line at Airport Rapid Transit Station and the Airport shuttle bus. This transfer could be eliminated by extending the Blue Line rail service directly into the Airport terminal area.

3. Transit passengers between Logan Airport and suburban corridors, other than the North Shore Corridor, must pass through the downtown transit system which is slow and congested and requires one or two transfers to reach the Blue Line. A direct suburban express bus would bypass the downtown congestion and provide essentially door-to-door transit service between the suburban areas and Logan.

4. Reasons similar to those stated above (downtown congestion, transfer requirements both downtown and at Airport Station) indicate the desirability of a direct bus service from downtown to Logan. Such service would be linked to a major bus terminal, such as Park Square, for passengers using intercity bus service and also to serve concentrations of downtown trips to or from Logan.

Results of the attitudinal survey clearly indicate a majority favor suburban express bus service, followed by eliminating the downtown transfer and replacing the shuttle bus with rail service and the lowest ranking preference being downtown express bus service.

Second and Third preference indicate a majority favor eliminating the downtown transfer.

Thus, the downtown transfer reduction ranks very high for all three (First, Second, Third preferences).

Preferences for Improvements to Existing Transit Services

Attitudes toward preferences for improvements to existing transit services were generally uniform for all persons interviewed, regardless of trip purpose, social characteristics, origin-destination or ground access mode.

Six categories of improvements were presented to those interviewed for selection as to First, Second and Third preference.

Service frequency and reliability ranked highest for the First preference, followed by cleanliness, feeder bus, information services and a low ranking for improved baggage facilities.

Second preferences again indicated highest ranking for service frequency, followed by cleanliness, service reliability, baggage facilities, information services and finally feeder bus.

Complaints Against Transit as a Means of Access to and From Logan

In addition to asking individuals to rank their preferences for improvements to existing transit services and new transit services, the individual was asked what improvements in transit service would be necessary to influence them to choose transit over other means of ground access to or from Logan. Also, if there were no improvements in transit service which would induce him to use transit, he was asked to explain why. The primary intention of the survey was to identify the reasons why more persons were not using transit to or from Logan; the two final survey questions focused on this purpose.

A summary of the above data was made in which the complaints against transit were ranked by the number of responses for each complaint. There were 300 responses with no complaints (due to the large number who were already transit users). Many of the individuals included more than one complaint. The rank order shows that time factors (service too slow, too many transfers, service too infrequent, poor reliability) are the overriding complaints against transit service and account for 190 complaints. Environmental factors (dirty, uncomfortable, too hot, too cold, noisy, lack of courtesy and personal danger) also rank high with 135 complaints.

Convenience factors (does not serve suburbs, no door-to-door service, always prefer private car, no "owl" service, poor baggage facilities, holiday service and station parking) rank high with 125 complaints. Cost factors (fares too high) rank low with 16 complaints, followed by 13 complaints concerning user information services.

Additional analyses were made to determine variations between transit and non-transit user complaints against transit. Close agreement was seen between transit and non-transit users for the following complaints against transit:

- No suburban service
- Uncomfortable
- Too hot or too cold
- Too noisy
- No owl service
- Lack of courtesy

However, there was a pronounced divergence between transit and non-transit users' complaints against transit for the following categories:

Factors more important to transit than non-transit users:

- Too many transfers
- Poor user information
- Poor baggage facilities
- Lack of public toilets
- Fares too high
- No door-to-door service

The various complaints were combined into the four basic categories of time, environment, convenience, and cost for transit and non-transit users. Analysis of the transit and non-transit user attitudes for these four general categories reveals very close agreement between transit and non-transit attitudes.

Results of the Origin-Destination Survey

Some preliminary results of the Origin-Destination survey for deplaning air passengers became available as this volume of the CASS Report was being completed, and are discussed in the following pages.

Approximately 50,000 person ground trips were made from Logan Airport during the average weekday in June 1970. It is estimated that in excess of 20,000 deplaning air passenger trips were included in the 50,000 person trips (it has not yet been determined from the survey the number of deplaning air passengers; it is estimated there are 21,500 deplaning air passengers based on 1968 data extrapolated to 1970). Previous surveys at Logan have shown that air travelers make up the largest single market for transit trips to and from the Airport. (Of the transit trips to and from Logan, 53% are air travelers, 24% work at Logan, 12% meet or see-off air travelers, 2% sightsee, and 9% are other or unknown.) Air travelers also comprise the largest segment of the total ground trip market to and from Logan (55%-65% of ground trips are made by air travelers). Thus, an analysis of deplaning air travelers accounts for approximately 50% of the potential transit market. (An analysis of non-air traveler trips to and from Logan has not yet been made since the data is not in machine processible form at this writing.)

Analysis of the deplaning air passenger trips destined for the Blue Line market area does not indicate encouraging results. Improvements to the Blue Line in the Northeast Corridor would benefit a relatively small number of one-way air passengers. There are approximately 1,480 deplaning air passenger trips from Logan to the North Shore market area towns during a weekday. Only 40 of these trips are made by transit which indicates a very poor modal split (2.7%). The towns which generate the largest number of deplaning air traveler trips (50 or more trips per town) in descending order of importance are: Lynn, Peabody, Marblehead, Gloucester, Beverly, Salem, Swampscott, Lynnfield, Danvers, Manchester, Revere, Saugus and Ipswich. Chelsea, Winthrop, and East Boston are not included in the above since

these areas would not be affected by Blue Line improvements at the corridor level (e.g., extension beyond Wonderland, express track between Pines River and Airport). East Boston, Winthrop, and Chelsea generate approximately 360 deplaning air passenger trips of which approximately 25 are made via transit (7%) modal split. Transit access improvements to Logan which would affect East Boston, Winthrop and Chelsea (e.g., rail spur into Logan or direct bus service) might be expected to attract up to 110 transit trips to these areas by deplaning air passengers (assuming an optimistic modal split of 30%). This traffic potential does not include Airport employees who are probably concentrated in the Blue Line market area and could account for a substantial transit market. Travel data for the 10,000 Airport employees is not yet available and can only be speculated on at this time.

Assuming that Blue Line improvements could generate a 30% modal split for the North Shore deplaning air passenger market (this is an optimistic assumption based on Cleveland-Hopkins survey results) then only approximately 445 transit trips (i.e., 400 new transit trips) could be expected from the deplaning air passenger market to the North Shore. Reasons for the existing low modal splits to the North Shore are discussed below which indicate difficulties in competing with the auto access mode.

The Western Corridor generates nearly twice as large a market for deplaning air passenger trips as the Northeast Corridor. The Riverside Line market area, which can be considered a subdivision of the Western Corridor, being mainly composed of Newton, Brookline, Framingham, Wellesley, Needham, and Natick, generates approximately 2,160 deplaning air passenger trips, which include approximately 150 transit trips (7% modal split). Based on the assumption that transit access improvements between Logan and this market area (e.g., extension to Framingham, upgrading and through routing Riverside Line) could produce a 30% transit ridership, then approximately 650 of the deplaning air passenger trips would use transit to these destinations (approximately 500 new transit trips would be attracted). Considering the total Western Corridor market which extends out beyond Route 495, the total number of deplaning passenger trips is approximately 3,160 of which 190 are transit (6% modal split). A 30% modal split for this expanded market area would generate approximately 950 transit trips (i.e., 760 new transit trips).

Comparison of the Western and Northeast Corridors shows both larger volumes (3,160 vs. 1,480) and higher modal splits (6% vs. 2.7%) for the Western Corridor which attracts nearly five times as many transit trips (190 vs. 40) as the Northeast Corridor.

The reason that a greater percentage of the deplaning air passenger trips are made via transit to Western Corridor destinations than to North Shore Corridor destinations might be explained by the large number of transit trips to Newton. Newton generates approximately 27% of the total trips to the Western Corridor and 8% of these trips use transit. Newton enjoys convenient access to the Riverside Line which passes through the center of town with seven transit stops in Newton. Conversely, the largest generators in the Northeast Corridor are Lynn, Marblehead, Beverly and Gloucester, which account for 35% of the trips to this corridor. These towns are located well beyond the Blue Line terminal and generate a low 2% modal split. Revere, which has three Blue Line stations within its boundaries, produces less than a 2% modal split for deplaning air passenger trips. The differences in Western and North Shore Corridor modal splits are believed to result from travel time factors. Travel time ratios (transit ÷ auto door-to-door travel times) and time differences (transit minus auto) for the Northeast Corridor are generally higher than for the Western Corridor. Out-of-pocket travel costs are not considered to be a major factor in transit use for air travelers; however, the transit travel costs to the Western Corridor are more competitive with out-of-pocket auto costs than for the Northeast Corridor (e.g., Tunnel and Turnpike tolls are high for Western Corridor auto trips which tend to make transit more attractive).

Analysis of the residence (Massachusetts resident or non-resident) of deplaning air travelers with destinations in the North Shore and Western Corridors indicates that approximately 50% of the trips to each corridor are made by non-residents of Massachusetts. The high percentage of non-residents can help to explain the low modal splits but does not explain differences in modal split between the Northeast and Western Corridors.

Boston accounts for 25% of the total deplaning air passenger ground trip destinations and represents the largest market concentration. Downtown Boston accounts for more than 60% of the deplaning trips to Boston (approximately 3,600 trips to downtown). Only 7% of these trips use transit (255 transit trips). The non-transit trips to downtown Boston are primarily taxi trips which account for over 50%; most of the remaining trips are equally split between private car and limousine (17% each); rental car trips account for only 5%.

Low modal split to downtown Boston can be explained by examining trip purposes. More than 60% of the trips to downtown are for company business which produces less than 4% modal split. This is probably due to the availability of expense accounts associated with company business trips. Approximately 30% of the trips to downtown are made for pleasure and personal business purposes; these trips exhibit relatively high modal splits of 12%-15%. Further examination indicates that over 80% of the deplaning passenger trips to downtown Boston are made by out-of-state residents which would account for the low transit and high taxi use.

The largest number of trips to downtown are concentrated in Zone 34 which encompasses Prudential Center (and Prudential Station). Approximately 20% of the trips to downtown are concentrated in this zone which produces a 2.8% modal split. Most of the trips to this zone use taxi.

The next largest concentration of trips are in Zone 30 which encompasses Park Square. Zone 30 accounts for 18% of the trips to downtown and produces a modal split of 4.6%. Most of the trips to this zone use taxi and limousine service.

The remaining trips to downtown Boston are distributed rather sparsely throughout the downtown but are generally located along the Green Line service area. It appears unlikely that an appreciable number of the downtown trips could be attracted to use the existing transit lines unless a major effort is devoted to advertising the transit service and actual use of the service is made considerably easier. Cleveland, for example, provides door-to-door service from the CBD while the Boston system requires two transfers from the Green Line area, which naturally inhibits use by air passengers unfamiliar with the system. Essentially door-to-door service will have to be provided to achieve high levels of transit use. The high concentration of trips at Park Square and Prudential Center indicates promising possibilities for a reliable door-to-door bus service between these areas and Logan.

The non-downtown Boston areas (e.g., Brighton, East Boston, Mattapan, etc.) were examined to determine market potentials. The non-downtown Boston areas account for 38% of the deplaning air passenger trips to Boston, or approximately 2,200 trips.

The non-downtown Boston destinations, unlike downtown Boston, generate a 16% modal split. This higher modal split is explained by differences in trip purposes for these two areas. Sixty-four percent (64%) of the trips to downtown Boston are for company business (which exhibits very low madal splits), whereas non-downtown Boston destinations attract only 39% company business trips. Fifty-two percent (52%) of the trips to non-downtown Boston are for pleasure and personal business, which trip purposes show consistently higher modal splits than company business trips. Jamaica Plain and Brighton attract the largest number of non-downtown trips (over 50% of the non-downtown trips) and produce 18% and 24% modal splits, respectively. The reason for these relatively high modal splits is that a large number of the trips to these destinations are pleasure trips which produce 27% modal splits and school trips to Jamaica Plain which produce a 35% modal split.

Cambridge is the largest attractor of deplaning air passenger trips next to downtown and non-downtown Boston. Cambridge generates a 16% modal split similar to non-downtown Boston destinations. This relatively high modal split results from a large percentage of pleasure, school and personal business trips which exhibit 20%-22% modal splits. Over 40% of the trips to Cambridge use taxi service followed by over 30% who use a private car.

Brookline attracts approximately one-tenth the number of trips attracted to Boston. Brookline generates a 13% modal split due to a high percentage of pleasure trips which generate a 16% modal split. The inner zones of Brookline, which have convenient access to the Green Line, produce a 14.6% modal split while the outer zones did not produce any transit riding. Over 50% of the trips to Brookline were made using private auto while 30% used taxi service.

CONCLUSIONS AND RECOMMENDATIONS FOR NORTHEAST CORRIDOR SYSTEM CHANGES

The Northeast Corridor alternatives, which were tested and analyzed during the course of this study (Alternatives 1-4), did not produce any significant net change in the modal splits and resulting total ridership demand when compared with each other. Since these alternatives all included an extension to Pines River with variations in feeder service to the terminal and with or without express track service, it has been concluded that the express track service is unjustifiable. The express bus feeder vs. railroad feeder must be evaluated in terms of operating and capital cost comparisons, since rapid transit ridership shows little variation with regard to these services.

Consideration of additional alternatives which were tested outside the CASS scope reveals strong justification for extending rapid transit at least to Pines River and preferably beyond to relieve the high parking demand at Pines River. In addition, a loop track into Logan Airport terminal attracts nearly 8,000 boardings at Logan, together with 4,000 boardings at Airport Station, which reflects an increase of nearly 5,000 station boardings due to the direct rail loop service. In spite of these encouraging ridership forecasts for the year 1990, the Logan rail loop is impractical as shown in the results of the engineering feasibility study (see Volume IV).

Although construction of the Wonderland to Pines River extension appears to be justified, it should not be made part of the proposed "Stage 1" construction program. The Authority staff believes that it should be possible to construct an extension for considerably less than the $28,650,000 estimated by the consultant. Since we are not recommending construction of the express line, the two-level terminal station recommended by the consultant would not be needed. By relaxing somewhat on standards of grade and curvature, it should be possible to design a shorter extension with a ground-level terminal which will have convenient access to parking lots and B&M Railroad trains. Such a design would also result in less disturbance to the Oak Island residential area and would minimize any possible damage to the ecology of the Pines River salt water marshes.

The Authority should work closely with the Massachusetts Department of Public Works, which is planning a Revere Beach highway connector from Interstate Route 95, so that an efficient rail-highway interface can be designed. Good design in this area would minimize the complexity and cost of access roads between the proposed parking lots and routes 107 and Interstate 95.

The spur to Logan Airport should not be built because of:

1. Its high capital cost.

2. Splitting of headways would result in a lower service level on the Blue Line leg north of Airport Station.

3. Preliminary data from the Logan Airport Travel Survey indicate a rather limited potential for attracting a substantial number of transit trips to the rail system without also improving or eliminating the downtown transfer inconveniences.

4. The spur cannot serve the individual airline terminals directly. Therefore, most travelers will have to transfer anyhow to reach their final destination.

A more feasible solution may be the construction of a light-weight elevated "people-mover" such as the Massachusetts Port Authority is studying. This system could have a connection to the existing Airport Station.

GENERAL COMMENTS

The structuring of a policy concerning the pricing and capacity of parking at various park-ride facilities and the pricing and capacity of parking in the core area should be made with prime attention paid to its effect on modal splits and resultant transit ridership. Once a trip maker has entered his auto for the peak-period trip, it is an extremely difficult task to divert him onto the fixed rail transit network, especially if the individual is a high-income, suburban resident. If a rapid transit line extension is to divert the present auto trip maker to the extension, either an extremely good collector to transit station system must be created, or easy access park-ride facilities along the extension, together with a very high level of

transit service (relative to the highway service), must be provided. These considerations, together with the structuring of a parking policy (both price and capacity) for the core area and park-ride lots, will have a significant impact on line extension ridership.

For those North Shore alternatives which involved express transit service, ridership was increased by approximately 1% per minute saved in total travel time. However, the ridership estimates for North Shore Preferred System (rapid transit extension to Tedesco coupled with the express from Pines River to Airport Station) showed an increase of nearly 10% (1,600 peak-period trips) over Alternative 3 (local service as far as Pines River). The express service, although providing a significant savings in total travel time (approximately five minutes), affects only that portion of the trip makers boarding at and north of Pines River. Thus, service is not improved for the inner, more densely populated areas which are the prime rapid transit markets, while service is improved for the suburban, higher income trip maker who is less sensitive to savings in total travel time than to reductions in excess time.

The following general conclusions can be drawn from the study results and from the discussion above:

1. If there is good auto access from suburban areas to high quality park-ride facilities along a rapid transit route, extending that line into low density, high income suburban areas will have little effect on overall line ridership even if park-ride facilities are established at stations along the extension.

2. High level feeder bus (or express bus) service can provide good access to transit stations from suburban areas, reducing excess time and increasing transit ridership. In addition, such service may also generate trips which previously had not been made, thus increasing not only modal split but also the total number of trips.

3. Express rapid transit provides an increase in the level of service for those trip makers residing in areas outside the initial station on the express line. However, in most cases these suburban dwellers are more sensitive to excess time than to total travel time and the express service, by itself, may have no effect on excess time. In addition, all intermediate station traffic will decrease because of increased

headways since the express trains do not stop at these stations.

4. Park-ride facilities have a significant effect in reducing access time and the proper design and location of these facilities can have an additional impact by reducing excess time and thus increasing transit ridership. However, these considerations must be coupled with policy concerning the pricing and capacity of core area parking relative to the price and capacity associated with each park-ride facility along the transit line.

CHAPTER 5

THE INNER CITIES AREA

The center of the urban region is most frequently defined as the central business district, or downtown. For purposes of examining the use of public transportation services, this definition can be extremely useful, particularly in studying specific types of trips. The Boston area exhibits some unique factors which appear to be gradually expanding the definition of the central area, in terms of the functions which take place there, the types of trips which are made there, and the people who live in the area.

Downtown Boston is extremely important in regional transportation and is indeed the focal point of much transit planning. It is not, however, the principal reason why public transportation services exist, or should continue to exist. Equally important are the many subcenters and high-density residential areas which are contiguous to, and feed upon, downtown's functions and the unique environment in which the functions are situated. Clearly, downtown Boston has the most important single aggregation of functions in the region, far outshining its nearest competition. Equally clear, however, is the influence of regional subcenters which exist within a densely-built residential web surrounding Downtown. They form a galaxy of geographic opportunities for regional residents, who respond differently, based on accessibility, costs, life styles, historical development and personal preferences. It is to the inner city neighborhoods which are focused on Downtown Boston that this report is directed. The definition of such a central area is, however, somewhat elusive, because of the many factors of which it is comprised.

DEFINITION OF THE INNER CITIES

Frequently, studies which deal with problems of inner-lying communities utilize the grouping of municipalities which are most closely focused on Downtown. This has come about because of the availability of data, which is generally provided only for aggregates contained within municipal boundaries. In the Boston area, there are serious difficulties in using municipal boundaries to analyze the Downtown-focused neighborhoods. The City of Boston is composed not only of intensively built downtown areas surrounded by older, high-density residential neighborhoods and work places, but also has within its boundaries major residential districts which can only be classified as suburban in character. These areas differ

distinctly in usage of public transportation, in total trip-making, in character of environment, often in life styles and the rate of participation in available work, and in social or recreational opportunities. Aggregations of data for Boston unfortunately tend to combine these distinctive neighborhoods into one unit, simply because of municipal boundaries. The same can be said of other municipalities. It is apparent that intensive examination of regional trip-making has acknowledged the distinctions in traffic generated in regional sub-areas and traffic which is oriented toward central business districts. Standard procedures exist for analysis of traffic on this basis, and these have been applied in Boston as in other major metropolitan areas. These procedures have been utilized to good effect in analysis of major inter-regional flows of traffic, and have provided a rich resource of data of extreme usefulness in preparing traffic statistics throughout the area. The data for Boston, supplied by the Eastern Massachusetts Regional Planning Project (EMRPP), have been used in the preparation of this report.

The data from the EMRPP, however, have not previously been utilized to determine whether there exists a specific sub-area of the region which does not fully mesh with traditional downtown-oriented traffic flow theory. For purposes of this report, therefore, the following assumptions were developed: There exists a number of inner city communities (or parts of communities) which exhibit distinctive environmental, socio-economic and trip-making characteristics. Although focused on, and related to, Downtown Boston, these areas show a complexity of trip-making patterns in which the traditional residential-to-downtown flows are not necessarily predominant. The areas are united, from a trip-making point-of-view, however, by the exhibited tendency for trips to be made for relatively short distances and to neighborhoods which are significantly related to functions of the regional core.

These assumptions formed the basis for the delineation of the Inner Cities Area in trip-making terms, as well as the socio-economic characteristics which distinguish it from the region. This is illustrated in the following sets of diagrams.

In a theoretical sense, an urban region spreads outward from a focus such as a central business district in equal distances in all geographic directions, assuming no constraints of topography. In Boston a major constraint working upon this theory is the existence of Massachusetts Bay and Boston Harbor. Here Boston got its start and it has served as the fountainhead of the growth of the region. (Figure 5-1)

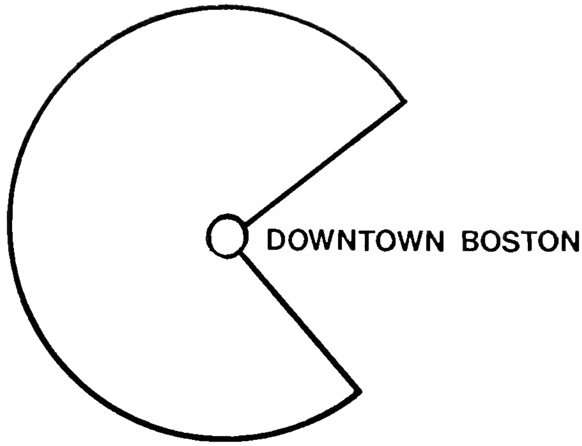


FIGURE 5-1

It has often been noted by students of the region that the growth which has taken place in this area and which has spread outward from downtown Boston has occurred unevenly. This has been particularly apparent in certain geographic districts which extend outward from the city. It has given rise to distinctions between these sectors in the extent of urban development, transportation services, attractiveness of real estate, and continued growth and urban expansion in each sector. Transportation planning has noted the existence of these sectors of regions as a basis for planning improvements. In the Boston area, for example, the examination of sectors has led to specific kinds of theory about ways in which traffic moves into and through the region, to, from and through downtown Boston, between sectors, and within sectors. (Figure 5-2)

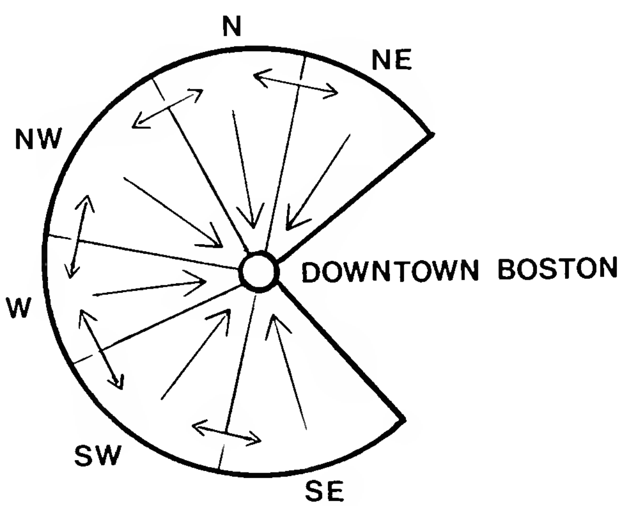


FIGURE 5-2

Such planning has produced uncomfortable conclusions in certain instances. For example, the cities of Cambridge and Somerville become corridors through which traffic moves to or from downtown Boston. In these cities, however, a majority of the movement does not appear to be oriented to downtown Boston. Both cities are, in a very real sense, important subcenters and attractors of people making trips within the region. In addition, both induce extensive trip-making within their boundaries. On closer examination it is quite apparent that there are many other such cities and towns. Towns along Route 128; such as Lexington, Waltham and Needham, with major accumulations of work places, are obvious examples.

It might be implied from these examples that the region is not adequately described in terms of sectors oriented toward downtown Boston, but is perhaps more properly composed of rings, concentric to downtown Boston. (Figure 5-3)

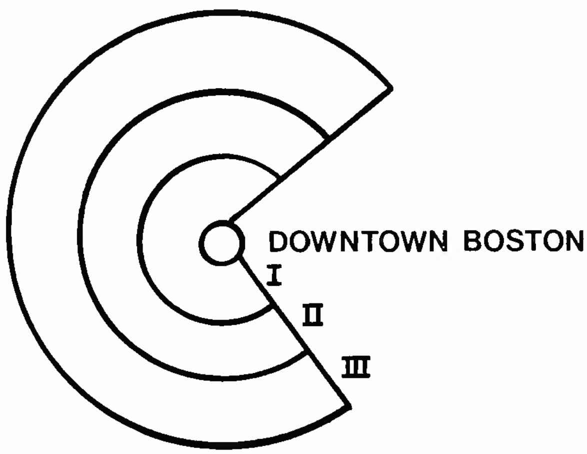


FIGURE 5-3

Ring 1, the closest to Downtown, is a district of high-density residential areas and unique work places and activities which are quite unlike those found elsewhere in the region. It includes many of the major educational and health facilities of the region, as well as nearly all of the activities oriented to the port of Boston. It includes the airport and most of the major cultural facilities available in the region. It is composed of most of the older areas of the region but includes many of the newest, high-density residential facilities being provided in the area.

Ring 2, by contrast, is distinctively suburban in character. Geographically, it is the area which lies on both sides of Route 128 and thus includes the low-density residential suburban areas of Newton, parts of Brookline and Boston, as well as newer suburban areas such as Peabody, Lexington and Braintree. Ring 3 includes the outer suburbs, an area of low density development which appears to be the setting of much of the newest residential development either underway of planned. Taken together, the three rings provide an alternative to sector theory in that they aptly illustrate increasingly denser development as one approaches downtown Boston.

This theory of urban rings contains some gross impurities, because there is evidence of urban expansion which is more pronounced in some sectors than in others. For example, the western sector has grown and is growing at a more rapid rate outward along transportation lines than, for example, the northwestern sector.

To account for the differences between sectors and rings, and the travel movements which are related in a gross sense to each of them, a composite of rings and sectors became necessary. This composite could not be adequately described by simple combination of the theories, however, because of certain unique features of the Boston region. The most obvious difficulty occurs in Ring 1, because of its intense interactive relationship with downtown Boston and the related functions which spill out into Ring 1 in random directions and in varying extent. Each of the associated areas provided reasons for determining the boundaries of the Inner Cities Area more broadly than either the ring or sector theories could afford. Downtown Boston is not adequately described functionally by a definition which uses Massachusetts Avenue as a boundary. The immense concentration of health and educational facilities in the Back Bay and in the Fenway distort this definition significantly. Cambridge is not adequately defined by sector, because of the extent of the unique functions which it contains - functions which draw not only from throughout Ring 1, but also from all geographic sectors to varying degrees. Somerville appears to be more closely related in trip-making to Cambridge than to Boston, even though it generates a substantial number of trips to Downtown Boston each day. By contrast Brookline - particularly North Brookline - is heavily oriented to Back Bay and downtown Boston in a traditional corridor sense.

The net product of this analysis is an approach which combines Ring 1 and Downtown to form a distinctive area, to be called the Inner Cities Area. (Figure 5-4)

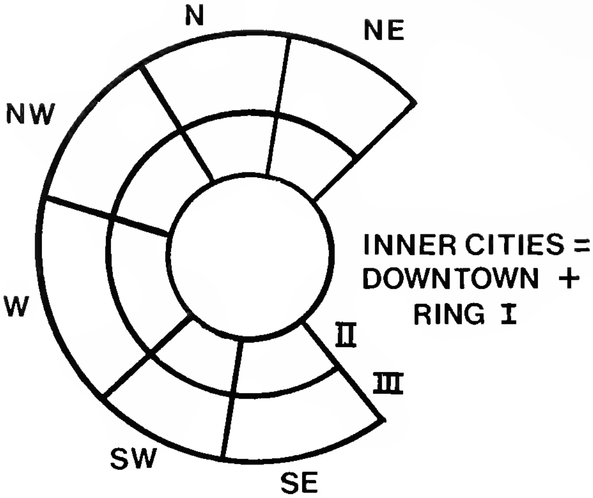


FIGURE 5-4

From an analysis of socio-economic characteristics, this area contains much of the region's population which is economically deprived, elderly, unmarried youth, unrelated individuals, students, and government workers. In trip-making terms, the Inner Cities Area includes much of the population which resides in autoless households, as a matter of choice or necessity, and are dependent on public transportation for access to work, shopping, recreation and other activities. A majority of downtown workers live within the area.

In terms of movement patterns, the area is extremely inward looking. (Figure 5-5)

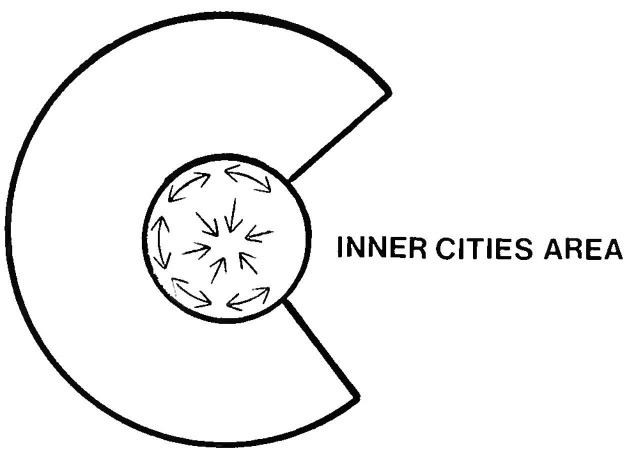


FIGURE 5-5

Most Inner Cities residents work in the Inner Cities Area. According to most recently available statistics, it does not appear that a great number of people leave the area either for pleasure or day-to-day activities. By contrast, the outlying portions of the region are much less dependent upon public transportation, much more mobile, and travel extensively between and within sectors for all purposes relating to activities which they seek. All of the sectors have some allegiance to downtown Boston, in terms of commuting for daily work purposes. Others commute to Inner Cities communities such as Cambridge. Specific portions of sectors have specific features which are worth noting. For example, Ring 2 sections of the Southwest and the Southeast Corridor exhibit a somewhat higher degree of relationship to Inner Cities functions than to other geographic areas. (Figure 5-6)

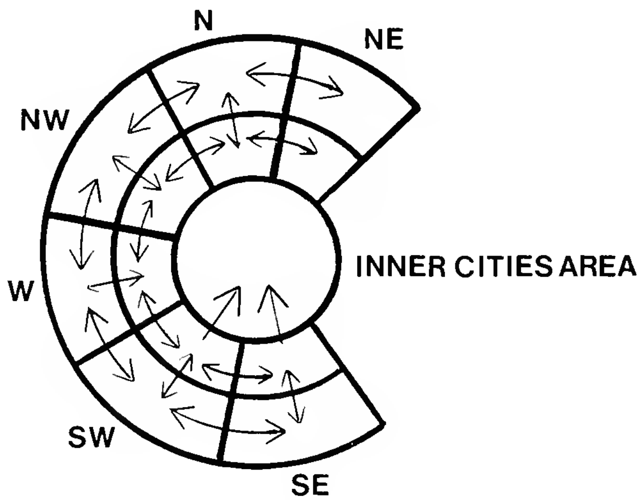


FIGURE 5-6

The characteristics of travel between sectors and downtown are most easily defined for sectors which lie outside Ring 1 and downtown in the Inner Cities Area. Within the Inner Cities Area, however, travel characteristics as diagrammed in Figures 5-3 to 5-5 are much more complex, and not so easily identifiable. A major reason for this is the existence of a basic differentiation of life style and subsequent use of public transportation within the Inner Cities Area. Movement patterns within the Inner Cities communities are reflections of high-density residential areas and the related concentrations of economic activity, including a great variety of subcenters or focal points of activities to which people seek access. (Figure 5-7)

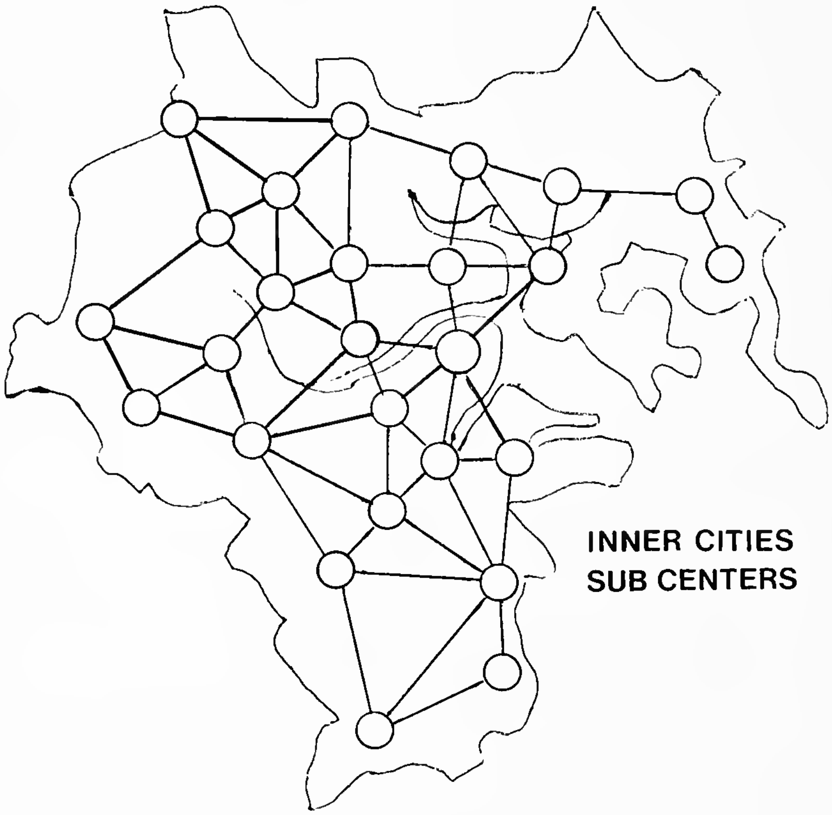


FIGURE 5-7

These focal points are nodes between which travel linkages have been established in a regional context. Downtown Boston is the most important of these nodes. Public transportation, to be effective in the Inner Cities Area, provides linkages between the nodes which provide access from residential areas to the great variety of desired destinations which lie within the Inner Cities.

Outside the Inner Cities, the focal points which exist consist of not only older centers of economic activity, but newer focal points, such as shopping centers. Because of lower density, the subcenters outside the Inner Cities Area tend to be more dispersed and at greater distance from one another. Competition from the automobile in such areas diminishes the need for public transportation analysis between all such nodes, quite in contrast to the Inner Cities Area. The volumes of traffic which are most

appropriate for public transportation in outlying areas between such nodes consist basically of traffic which is radial to the Inner Cities Area and to downtown Boston. The result is a series of nodes in outlying areas which can justify public transportation access only if it is primarily radial to the Inner Cities Area or to downtown Boston. Within the Inner Cities Area by contrast, there exists an interconnected series of nodes which requires public transportation access in nearly all directions. (Figure 5-7)

The consequences for public transportation services are significant. The need for movements between outlying centers of activity and the Inner Cities Area is met by both public transportation and the automobile. Certain of these areas lie in sectors of travel which have substantial volumes of traffic destined for downtown or Inner Cities locations. Most such sectors do not possess sufficient highway capacity to handle desired movements. Rail rapid transit extensions in such sectors are very useful ways of supplementing highway capacity, particularly if the rail extensions can develop sufficient capabilities to effectively compete with the automobile. To be fully warranted, rail extensions must exhibit significant projections of traffic volumes which can be handled effectively by only the rail modes. The rail transit extensions which the MBTA are now building include provisions for high-speed service, an interface with major regional highways, and wide station spacing, providing express lines through the Inner Cities Area communities to downtown locations. Access to outlying stations is principally by automobile although an extensive amount of feeder bus service will supplement such access. Substantial numbers of riders will be attracted to the new services because of the extensive provisions being made for competition with automobile travel.

Within the Inner Cities Area, as it is herein defined, these new services do not meet all needs, and were not intended to do so. Public transit riders in the Inner Cities will benefit in a major way from long rail transit extensions only if they reside close to rail stations on the new extensions. Inherent in the design of the new extensions are the following weaknesses:

1. The service does not provide well for riders travelling short distances.

2. The radial rail corridor does not lend itself to the movement between the subcenters (portrayed in Figure 5-7) which lie close to one another and which are not organized in radial fashion.

3. Cross-town movements, as opposed to radial movements are currently provided by bus and will continue to be because buses serve more directly certain needs than will the downtown-oriented rail rapid transit extensions.

4. Extensions to existing rail lines can have two undesirable side effects on existing portions of those lines:

    a. To assure an express line for suburban commuters, it may be necessary to reduce the frequency of service to the inner stations of the existing line.

    b. To achieve economical costs of right-of-way, some lines will be displaced into new locations which require feeder bus access, and which will add to the total trip time of many Inner Cities Area riders.

5. Certain of the links between subareas in the Inner Cities communities are more desired than others. The result is an accumulation of traffic on specific links, which includes both radial and cross-town movements, most of which are not sufficiently large in volume to warrant consideration of rail transit.

6. Although the rail transit extensions provide improvements in speed, access to and from these lines by Inner Cities Area residents may include extensive transferring and hence waiting times which may be acceptable for longer trips but do not represent improvements in service to Inner Cities riders.

These factors have pointed toward the need for a careful approach to the problem of improving service within the Inner Cities. Intensive examination of the problem as part of the CASS Project has led to specific findings concerning the characteristics of Inner Cities residents and trip-making, which will be useful in improving services to the older centrally located areas of the region.

DESCRIPTION OF THE INNER CITIES AREA

The search for a more precise definition of the Inner Cities Area has isolated appropriate criteria which would permit geographic limits. A composite of factors has been selected to differentiate between the Inner Cities and the remainder of the metropolitan area. These factors are comparable to those used in defining corridors which are precise, and which ignore municipal boundaries where necessary. The basis is zonal subareas of municipalities. In defining the Inner Cities, these zones have been helpful in permitting distinctions between portions of towns, such as Brookline,

which strongly exhibit both Inner Cities and suburban sector trip-making and socio-economic characteristics. This process has recognized differences within municipalities which are frequently overlooked. In reality, of course, these lines are not hard and fast, but tend to fluctuate with population changes. For reporting purposes, however, it was necessary to assume some degree of stability to permit analysis to progress.

A starting point in isolating the characteristics of the Inner Cities was an extensive search of literature devoted to differentiating urban areas on a basis of geographical separations between communities or subareas of communities. In the first round of analysis socio-economic characteristics available from the Eastern Mass. Regional Planning Project were examined. Certain broad regularities between communities were discovered to exist through statistical analysis. Irregularities appeared which were graded and measurable. The analytical process sought variables with the greatest significance in portraying socio-economic differentiations. A composite of these variables was prepared to illustrate intra-regional differences. Two processes were used as a check of the validity of the findings. The first method - a composite index - was based on the following elements:

1. Population density
2. Dwelling unit density
3. Automobile ownership per capita
4. Family income
5. Place of work - type of employment
6. Use of transit per capita
7. Employees per acre
8. Proportion of elderly
9. Proportion of residents in non-family groupings
10. Residential units not occupied by owners

The second was a method developed for a socio-economic study of the City of Los Angeles. The use of these two methods combine to form the geographic limits of the Inner Cities portion of the Boston region. (Figure 5-8)

It should be noted from this map that the defined area closely coincided with the core communities most often represented as being heavily urbanized and transit-oriented. It is within this area that the best market for public transportation has traditionally existed. This market has been in existence for many years and represents a broad cross-section of population which uses public transportation for many purposes. The area is noteworthy because it does not use public transportation solely for purposes of commuting to work. In a subregion which contains 30.9% of the region's population, it is distinctive because it includes 57.3%

A-A INNER CITIES AREA

B-B CIRCUMFERENTIAL HIGHWAYS ROUTES 128 & 3

C-C MBTA DISTRICT

FIGURE 5-8

of all the people who work in downtown Boston, it includes 68.8% of all the people who work in Cambridge and represents at least 62.6% of all of those residents who ride transit for access to work. The area includes major employment sources and, taken as a whole, 512,370 people are employed within the area every day. According to this definition, several minority groupings of population are extremely well represented; for example 39.3% of the elderly over 60 years or more live in the area. Fifty-one point four percent of the individuals not living with families live in this area, 41% of the families with less than $3,168 (in 1963 dollars) income live in this area. At least 66% of those household units without cars live in the area and 21% of those families having only one car live in the area. Population density is the highest of the region with 228 people per acre residing within these boundaries. A majority of the housing units which are not single family are found within this area. In a region known for its educational facilities; most of the institutions of higher learning are located in the area - in one small area, Back Bay - 28 institutions of higher learning are concentrated. A majority of the regional health services are located in the area. Most of the larger hospitals and nearly all of the medical training institutions are grouped within this small area. As a by-product of the concentration of educational and health training facilities, a majority of the region's 200,000 students find a focal point for most of their activities in the area and, in fact, most of them reside within the area. A concentration of an extensive number of young urbanites (people who prefer the city environment) as well as those who are economically underprivileged combine to make the Inner Cities Area distinctive from not only suburban areas but from other cities as well.

In summary, within a geographic area of 48,156 acres, there is concentrated many of the region's assets and liabilities as well as the region's prime market for public transit. Public transportation services which are provided in this area will be discussed in Chapters 6 and 7. As a framework for that discussion, it will be recalled that the Inner Cities Area is composed of those functions which are traditionally identified with downtown and those geographic areas which are contiguous to, and fairly closely related to, the downtown area. Outside the Inner Cities area, suburban areas will be handled as one unit, with discussion based on those services which extend from the Inner Cities Area outward in a radial fashion.

CHAPTER 6

THE CENTRAL SUBWAY AND THE MBTA SYSTEM CONSTRUCTION, HISTORY AND OPERATION

The Central Subway consists of five segments of grade-separated right-of-way between Kenmore Square in the Back Bay and Lechmere Square in East Cambridge, and is used by streetcars operating to and from surface lines in the south and west.

The first segment to be built was the Tremont Street Subway, completed in 1898, with surface inclines on its southerly end at Pleasant and Tremont Streets, and at Church and Boylston Streets in the Public Garden, and extending along Tremont Street to Scollay Square, and under various streets to a northern surface incline at Canal and Causeway Streets. This subway was designed for small surface cars operating singly, has numerous grades and curves, and a small cross section.

The second section to be opened was the East Cambridge Viaduct, in 1912. This commenced at the northern portal of the Tremont subway and extended over Causeway and Lowell Streets and the Charles River to a surface incline at Lechmere Square. The north and south ends are ballasted deck elevated structures, while the portion over the river is an open deck concrete viaduct. The alignment and profile of this extension are superior to that of the Tremont subway although there are two relatively sharp curves. The cross section is more generous than that of the subway, as well.

The Boylston Street Subway was completed in 1914, and extended from Charles and Boylston Streets, via Boylston and Newbury Streets, to a surface incline at the present Kenmore Square. The original Public Garden incline of the Tremont subway was closed and replaced by a new incline in the center of Boylston Street as part of the work. Originally, the Boylston subway was planned to connect with a new subway through the downtown area. Due to controversy over the route of the latter facility, the Boylston subway was completed and temporarily connected to the Tremont subway while the route of the downtown link was settled. No such subway was ever built, and the "temporary" connection remains in use today.

The Boylston subway was built to alignment and clearance standards far superior to those of the original subway, and comparable to the standards for the Cambridge Subway, completed a short time previously.

To eliminate surface car operation through Kenmore Square, a new subway station and connecting tunnels was opened in 1932. The original incline was closed, and replaced by a four track station incorporating a grade separated junction. Two of the station tracks continued in tunnel to a surface incline at Blandford Street and Commonwealth Avenue, while the other two tracks were carried under the Boston & Albany Railroad to another surface incline at Beacon and St. Mary's Streets. The station and tunnels were built to the standards of the Boylston Street subway. The center tracks at Kenmore station were built on trestlework in anticipation of future high platform operation, and the Blandford incline was likewise constructed to permit subway extension. The Beacon Street tunnel was modified in 1959 when a double track non-grade separated junction was added, along with a short connecting tunnel and surface incline, to permit through operation to and from the Highland Branch.

The last major construction as part of the Central subway system was the Huntington Avenue Subway, completed in 1941. This facility extends from a connection with the Boylston subway at Exeter and Boylston Streets under Huntington Avenue to a surface incline at Opera Place. The incline is built on trestlework to permit further subway construction. The junction with the Boylston subway is in the form of a flat double track intersection, and the curve extending from the junction into Exeter Street is of small radius. The remainder of the subway is built to the standards of the Boylston subway.

The relative length of the segments is shown below:

Tremont Street Subway	1.35 miles	23%
East Cambridge Viaduct	1.17	20
Boylston Street Subway	1.45	25
Kenmore Station and Extensions	1.07	18
Huntington Avenue Subway	0.83	14
Total Central Subway	5.87 miles	100%

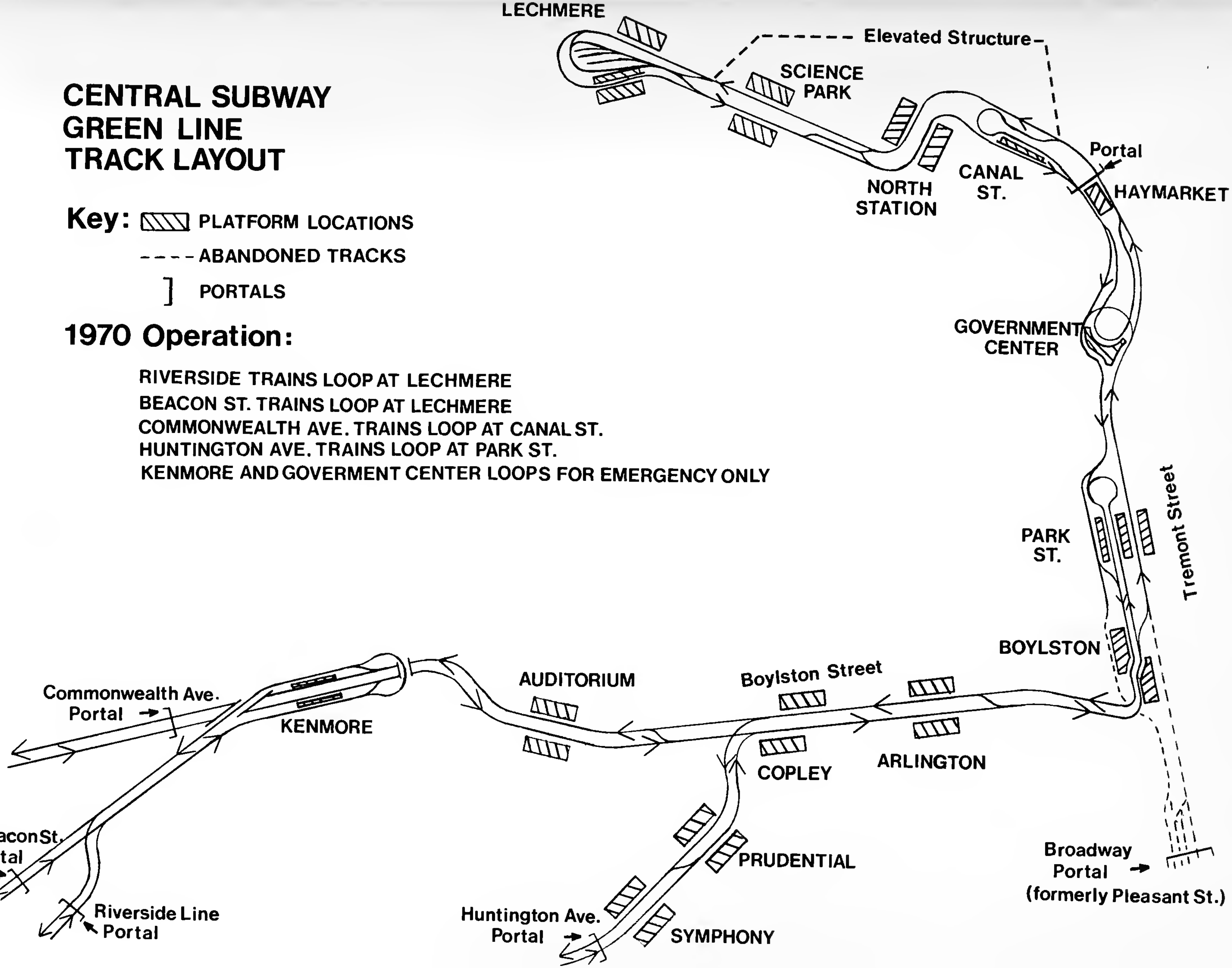
See Figure 6-1 for a schematic view of the Central Subway track layout.

CENTRAL SUBWAY GREEN LINE TRACK LAYOUT

Key: ▧ PLATFORM LOCATIONS
- - - - ABANDONED TRACKS
] PORTALS

1970 Operation:

RIVERSIDE TRAINS LOOP AT LECHMERE
BEACON ST. TRAINS LOOP AT LECHMERE
COMMONWEALTH AVE. TRAINS LOOP AT CANAL ST.
HUNTINGTON AVE. TRAINS LOOP AT PARK ST.
KENMORE AND GOVERMENT CENTER LOOPS FOR EMERGENCY ONLY



CENTRAL SUBWAY AND SURFACE LINES - ROLLING STOCK

At the time of the construction of the first section of the Central Subway, the largest surface vehicle operated was an eight wheel wooden passenger car, 35 feet in length and 7'10-1/2" in width, with a seating capacity of 34 and a total capacity of 88. These cars had open platforms, two motors, hand brakes, and were operated with two man crews as single cars only. Large numbers of these vehicles, including open sided versions, had been purchased in the eight years prior to 1897 when the street railway system was converted from horse to electric motive power. It was around this type of vehicle that the Tremont Street subway was designed. The many steep grades and sharp curves in that subway were no more severe than what was already present on many surface lines, and the provision of a route free from other traffic permitted considerably higher operating speeds and more frequent car service in the downtown area.

The continued growth of street railway patronage, coupled with rising labor costs, brought about the development of larger vehicles. Beginning in 1905 the Boston Elevated acquired cars 46 to 48 feet in length and 8'6" to 8'8" in width, and with seating capacities of 48 to 62 passengers, and total capacities of 151-174. Shortly thereafter multiple car operation was developed, with two car motor trains being put into service in 1914, and three car motor trains being introduced in 1917. Up to 1914 all cars had been of the traditional end entrance type, but with such improvements as air brakes, four motors, and sliding and folding power operated doors. In that year a series of center entrance trailer cars was purchased. These vehicles had a low body floor with a large drop center well with large sliding side doors, and were used with older motor cars. In 1917 a motorized version was acquired for operation in train service, and although used on many surface lines, the type was principally assigned to heavy routes feeding into the subway. Because of their door and step configurations, the center entrance cars proved to be extremely good loaders of crowds in the subway, and were used in this service until 1953.

The last locally designed vehicles for surface line operation were purchased in 1928, and no new cars were acquired for eight years. In 1936 a sample PCC car was received, and was used on surface lines from Arborway car house. In 1941 a group of 29 additional cars of this type were bought, specially fitted with left hand doors for subway operation, and assigned to Watertown car house.

The PCC car was designed by the Transit Research Corporation under the sponsorship of a committee of street railway presidents in an effort to develop a modern standardized surface car. It was a single end car, with a level floor, and two right hand side doors. In terms of many of the streetcars in service nationally at that time, it was a very advanced design, but the application in Boston, first with one left hand door for subway-surface operation, and later in multiple unit service, was a case of making alterations to a standard design to fit a non-standard application, resulting in a less than satisfactory product.

During the early years of World War II, the pressure of mounting traffic, and the presence of an aging fleet of surface cars caused the Boston Elevated to seek additional cars of this type. A number of cars were acquired through War Production Board orders, and additional cars were purchased through 1951, the last series of 50 being of a design unique to Boston although using PCC components. The last of the older multiple unit cars were taken out of service in 1953, and 1959 saw the retirement of the final group of locally designed vehicles.

System wide, the numbers of the various types of surface rail vehicles and their period of use is tabulated below:

Horse Cars			1717
Closed	1856-1903	948	
Open	1856-1903	769	
Small Electric Cars			3281
Single Truck Closed	1889-1920	459	
Single Truck Open	1889-1919	1351	
Double Truck Closed	1890-1927	1244	
Double Truck Open	1890-1919	227	
Large Electric Cars			2230
#1-5 Semi & Birney & Foreign	1905-1959	1087	
Center Entrance Motor & Trailer	1915-1953	616	
Articulated	1912-1925	181	
P. C. C.	1936-present	346	
Total			7228

The maximum number of vehicles on the property at one time was 3396 in the year 1915.

Figure 6-2 is a photograph of a typical PCC car.

A PCC Car

FIGURE 6-2

CENTRAL SUBWAY - TRACK ARRANGEMENT

The Tremont Street subway was constructed with two through tracks from the Pleasant Street incline to the Canal Street incline, with additional double track sections between the Public Garden incline and Park Street loop and between the Canal Street incline and the Brattle loop. At the Pleasant Street incline the two subway tracks split into four surface tracks by means of a grade-separated junction.

Boylston Street station was so constructed that the two through tracks were each adjacent to the outer walls of the subway, and the tracks from the Public Garden crossed over the southbound through track and became the center tracks in the subway, creating a grade-separated junction between the through and loop tracks. At Park Street, in addition to the loop for the center pair of tracks, a loop connection was provided for turning cars on the through tracks from north to south. At Scollay Square the subway divided, with northbound cars travelling under Cornhill and Washington Streets to Haymarket Square, and southbound cars returning under Hanover Street to Court Row. Each of the uni-directional sections was built as a double track tunnel, through cars using the right hand track, and Brattle loop cars using the left track. North of Hanover and Washington Streets there was a section of four track tunnel, and then an incline to the surface. A reversing loop for northbound cars was provided on private land between Canal and Haverhill Streets. In contrast to the grade separated arrangement of routes in the majority of the subway, the northern incline was laid out on one level, with connecting tracks and crossovers permitting movements between the four subway tracks, the loop, and street trackage. A control tower was provided, and switches were mechanically operated by signalmen.

The construction of the Lechmere extension in 1912 provided a grade separation at the northern incline, as the two outer or through tracks of the subway were connected to the two tracks of the viaduct. At the East Cambridge end, the tracks descended to private land at street level, and a flat double track junction was provided to enable cars to reach existing surface trackage.

Construction of the Boylston Street Subway provided a double track extension of the two center or Park Street loop tracks of the original subway, from Charles Street at the foot of the old Public Garden incline to a new incline at Kenmore Square.

In order to accommodate certain car lines (notably Berkeley Street and Huntington Avenue routes) the Public Garden incline was replaced by a new ramp in the center of Boylston Street. The two tracks extending from Park Street to Kenmore Square were widely separated between Charles and Church Streets, and the two tracks to the surface diverged in the space between, creating a grade separated junction. At Kenmore, the two incline tracks passed through a surface station, and then diverged by means of a flat double track junction into Commonwealth Avenue and Beacon Street.

In 1922 a prepayment station was built at Lechmere Square. The two viaduct tracks were terminated in a reversing loop and small storage yard, and a separate grade separated reversing loop was provided for surface cars, which henceforth operated independently of viaduct-subway cars.

When Kenmore Station and the connecting tunnels were built, the double track trunk line of the Boylston Subway continued through the center tracks of the station and on to the Blandford Street incline. Just east of the station platforms, one additional station track diverged from each through track and passed through the station on the outside of the two island platforms. West of the station these two tracks converged, with the outbound branch track passing over the two through tracks, and continued in a long tunnel to the St. Mary's Street incline. In addition, an underground reversing loop was provided east of the station, so that inbound cars from the Beacon St. branch could reverse direction, the loop track passing over the two through tracks.

When the Huntington Avenue subway was constructed, a flat double track junction was effected with the Boylston St. subway just west of Copley Station. The double track then continued to the Opera Place incline. At Symphony station the platforms are separated laterally, and each track is adjacent to the outer walls of the Huntington Ave. auto underpass. Huntington Avenue cars, which formerly entered the subway at the grade separated incline east of Arlington station, now used the Huntington Ave. subway and joined cars operating in the Boylston subway by means of a flat junction.

When the Highland Branch of the Boston & Albany was converted for streetcar operation, connection was made with the Beacon St. subway west of Kenmore by means of a double track flat junction. At about the same time, revenue service over the through tracks of the original Tremont subway between the Pleasant St. incline and Boylston St. station was discontinued, and connection was

broken with the operating trackage. Part of the flying junction at the Pleasant St. incline had been unused since the closing of streetcar service to City Point in 1953. Revenue service over the center tracks of the subway between the Haymarket portal and Brattle station had ceased in 1953, but the trackage between the west end of Haymarket and Brattle has been kept intact for live storage and emergency service.

Scollay Square station and certain of the tunnels north thereof were reconstructed in 1959. The basic change was that the former northbound through track and Brattle loop track running via Cornhill Street was relocated to a more direct course between the station and the corner of Hanover and Washington Streets. In addition, a new reversing loop was provided to permit northbound through cars from Park St. to reverse direction just north of the reconstructed platforms. The new loop track crosses both Brattle loop tracks at grade.

The former outside loop at Park St. (permitting north to south reversal of cars on the outside through tracks) was removed in 1961, and a new southbound crossover was constructed between the southbound through track and the southbound side of the Park St. loop. This connection permitted a choice of two routes for southbound cars operating between Scollay Square and the center tracks at Boylston Street, and speeded up loading at the Park St. southbound platform.

At the present time, the normal operating route through the subway is as follows: From Lechmere, via the viaduct southbound to the outside track at Haymarket, then via the through track to the outside track at Park St., then crossing over to the center track and via the westbound Boylston St. subway to the east end of Kenmore Station. At this point, and further along in the Beacon St. tube, diversions are made as appropriate to surface trackage. Southbound, trackage enters the main track from the Canal St. loop and then leaves to enter the Brattle loop. At Park southbound only, either the wall track or center track may be used. South of Park St. a section of the former through track remains in place for live storage. At Copley, the outbound Huntington Avenue track crosses the inbound Boylston track.

Track usage in the northbound direction is similar, with the main difference being that all cars destined north of Park St. must cross to the outside track just north of Boylston Station.

With the opening of the complete Tremont Street Subway in 1898, the routing pattern was as follows: All northbound cars entering at the Public Gardens terminated at the inner loop at Park St., cars entering via the Pleasant St. incline ran through to Haymarket, and cars entering at North Station either ran through to Pleasant St. or terminated on the Brattle loop. Some cars entering at Pleasant St. either terminated in the Canal St. loop or ran through onto surface streets. The lack of a grade separation at the Haymarket portal necessitated crossing movements, as it would not have been practical to operate a non-conflicting service pattern (i.e., Canal St. loop - Brattle loop as one routing, and surface tracks through the subway to Pleasant St. as the second routing).

The nature of the traffic on the various surface lines feeding the subway at that time resulted in the Public Gardens incline to Park St. loop routing becoming the most heavily used of the three major subway routings. Within a year after the opening, a rate of 195 single cars per hour was achieved. The problem of multiple destination loading restricted flow at first, but a system of advance notification of passengers removed this block. Within a few years thereafter, it was established that the maximum practical capacity of a subway track was 240 single cars per hour, and of a surface track, 160 cars per hour.

Because of the heavy flow of cars to and from the Public Gardens portal, all were routed to Park St. without crossing other cars to and from the through tracks of the subway.

In 1901 the so-called through tracks, namely the outside pair of tracks between Haymarket portal and Scollay, the two tracks between Scollay and Park, the two outside tracks from there to Boylston, and the two tracks to the Pleasant St. incline, were taken over for third-rail train service, and connected at either end of the subway to elevated structure. The Public Gardens to Park St. service continued unchanged, and cars entering from the surface at Canal St. used the Brattle loop exclusively. Because of the institution of elevated service, a number of lines formerly using the subway were rerouted to surface terminals in the downtown area or eliminated entirely. Elevated train operation in the Tremont subway continued until 1908, at which time that service was rerouted to the new Washington St. tunnel. The maximum train length in the 1901-1908 period was 5 cars, and the minimum headway was 90 seconds, although that headway was not operated continuously for any length of time.

After the removal of elevated service, and the restoration of certain surface lines to the Central Subway, it appears that the original operating pattern was followed. With the construction of the Lechmere viaduct, several lines formerly entering the subway from Causeway St. west were routed over the viaduct, principally through the subway to Pleasant St. Lines from Charlestown ran to the Brattle loop, including cars of Bay State Street Railway*, but some routes continued to cross from one track to another at the Haymarket portal.

With the opening of the Cambridge subway, a number of long surface lines from the northwest formerly running through to Park St. via Boylston St. were eliminated from the subway, reducing the flow of vehicles on the Public Gardens - Park St. link. It seems that after this change certain routings were instituted which required cars to cross between tracks in the Boylston - Park St. section, so that cars from Pleasant St. now ran to both North Station and Park St. loop, and cars from the Public Gardens did likewise. With the completion of the Boylston St. subway, cars formerly entering via the Public Gardens were routed as follows: Cars from Brighton Ave., Commonwealth Ave., and Beacon St. used the Kenmore incline, while Ipswich St., Huntington Avenue, and Berkeley St. cars used the new incline in the center of Boylston St. opposite the Public Gardens. In the years immediately following, multiple car operation was introduced, first with Type 4 semis hauling center entrance trailers, and then with center entrance motors running in two and three car trains.

A detailed study of the entire surface lines operation of the Boston Elevated was made in 1917, and from it a reconstruction of central subway operations can be made. Train length is not specified, although at the time the maximum length would have been 2 cars, and a number of routes used single cars only. By point of entry the number of peak hour units is as follows: Kenmore, 37; Public Gardens, 48; Pleasant St., 50; North Station surface (excluding Bay State cars), 16; and Lechmere, 26. Peak load point was the Park St. loop with 92 units, with the next highest volume being 85 units between the Public Gardens incline and Boylston St., and the third highest flow being 50 units from the Pleasant St. incline to Boylston. The contrast in service levels between 135 units entering at the two southern portals and 66 units entering the Haymarket portal (including cars looping at Canal St.) may be noted. The number in crossover movements is interesting. Between Boylston and Park northbound 21 units crossed from outside to center tracks, and 14 units made the reverse movement. Between North Station and Haymarket southbound, 18 units crossed from outside to center tracks, while 35 crossed from center to outside tracks.

*Predecessor of the Eastern Massachusetts Street Railway

Where Huntington Ave. (and other) cars entered the subway opposite the Public Gardens, it was at the rate of 48 units per hour, merging with 37 units from Kenmore. The reverse movement was grade separated, with 48 units leaving the subway out of a total of 85 units south of Boylston St. station. If this junction had not been grade separated, the inbound track would have had to accommodate 37 cars from Kenmore + 48 cars from the surface + 48 outbound cars to the surface for a total of 133 units.

It may be seen that where a relatively large number of lines are accommodated (22 in the 1917 example) operating over several different routings, many of them conflicting, careful planning must be given to avoid overcrowding the facility at busy times.

Returning to a review of operations in the Central Subway through its existence, from 1917 on the form of the facility remained unchanged until 1932, but several factors brought about a reduction in vehicle movements. At the opening of the Boylston subway, all schedules were handled by single unit cars, either the small West End cars or the newer and larger Boston Elevated units. Trailer operation was introduced in 1914, followed by multiple unit operation. Three car trains were first used in the subway on the Beacon St. line in 1919, and all of the heavier lines were eventually served by multiple car units. In the same period the Elevated began to reduce the number of routes operating on the system as a whole, concentrating through service on trunk lines, and lengthening the headway on less productive secondary segments. Additionally, starting in 1922 a number of the lesser street car lines were converted to motor coach operation, and through operation to the subway was terminated.

The opening of Kenmore station and approaches was not accompanied by any routing changes, but the elimination of surface operation through the square resulted in reduced running times and improved reliability. The grade separation of the Beacon - Commonwealth junction was also a factor. In the following years, the reduction in employment and corresponding decrease in personal income on account of the Depression brought about less transit riding, and schedules were adjusted accordingly. The completion of the Huntington subway, and the closing of the incline east of Arlington station came when the country was entering World War II and was converting to a defense economy, bringing about greatly increased riding. At this time only 8 basic lines were operated in the subway, with some additional tripper services. The peak

in vehicle movements appears to have occurred in 1947, after which time increased use of private automobiles caused reduced transit riding.

Available tabulations show that the peak load point in the subway in terms of scheduled movements for many years has been the section just west of Boylston station. Until 1941 the west limit of the section was the surface incline at the Public Gardens, in which year it was removed to the junction at the west end of Copley station. In 1926 113 units totalling 241 cars per hour were scheduled through this section. By 1938 the figures had declined to 80 units and 139 cars, and rose again to highs in 1947 of 98 units and 206 cars. These extremes reflect total car movements. During World War II the highest number of units recorded was 106 in 1942 (with 169 cars).

Analysis by the Timetable Department of the Central Subway operation in 1946 indicated that the minimum practical headway on clear signal indications was 30 seconds, giving a maximum flow of 120 units per hour, at an average speed of 13 miles per hour. Operating on yellow signals a 20 second headway or 180 units an hour could be operated, but this practice was not considered satisfactory. Each unit could consist of one, two, or three cars, but the possibility of operating longer trains was not investigated. If 120 units of 3 cars each were operated, a per hour rate of 360 cars would be possible, in contrast to the 240 single car rate. However, it appears that no more than 67% of this theoretical capacity was ever scheduled.

By 1953 the surface lines operating into the subway from Causeway St. on the north and from Broadway on the south had been converted to motor bus operation. The last line using the Pleasant St. incline, the Tremont St. to Lenox line, was converted to bus operation in 1959. Even in advance of these changes, the principal flow of traffic for some time had been from the Boylston St. subway to North Station and Lechmere and return, in the form of one double track trunk line. The Canal St. and Park St. loop trackage merely provided reversing capability without additional capacity.

The closing of the Tremont St. line resulted in the retirement of certain running trackage in the downtown areas, while the addition of the Highland Branch used the full length of the Boylston St. subway. This line was connected by means of a flat junction similar to the Huntington connection, but the relatively low number of movements, involving only two lines, did not create a great amount of congestion. In contrast, the

junction at Copley is used by all Boylston subway routes, and is a source of regular delays.

In 1969 the Watertown line was converted to bus operation on an experimental basis, but Commonwealth Ave. service was increased correspondingly. As of the spring, 1970 timetable, maximum flow through the Boylston subway from Copley to Boylston stations was 66 units and 164 cars per hour. The number of units is 62% of the 1942 high and 55% of the rated capacity, while the number of cars is 80% of the 1947 volume and 46% of the practical capacity based on 3 car trains. It might be noted that the average train length in 1970 was 2.48 cars, a reflection of single and two car train service on Huntington Avenue. In the maximum hour, the service through Copley junction was 26 units and 44 cars to Huntington Ave. and 40 units with 120 cars continuing to Kenmore. On the inbound track, 66 units must be merged from Kenmore and Huntington, and in addition 26 outbound Huntington units must be intersected, for a total of 92 units, while the rated capacity is 120 units. Present operating rules prohibit simultaneous occupancy of the junction by inbound and outbound trains on the Kenmore route. One way to analyze the effect of this ruling is to consider outbound Kenmore units as outbound Huntington units in calculating junction movements. Sixty-six inbound units must be intersected by 66 outbound units, for a total of 132 train paths, compared with a capacity of 120 units.

At Park St., Government Center, and Canal St. the junctions merely permit northbound cars to reverse direction, and basically have no effect on capacity, the number of units and cars through each section of the subway being variable according to traffic needs.

MAIN LINE (ORANGE LINE) - CONSTRUCTION

The first high platform rapid transit line to be opened in the city was the elevated route between Sullivan Sq. and Dudley St. via Washington St. in 1901. The middle section of the route, between Beverly and Causeway Sts. and Pleasant St. and Shawmut Ave., used the two through tracks of the Tremont St. subway, opened two years previously.

An additional section was opened in the same year, via Commercial Street, Atlantic Avenue, and Harrison Avenue and connecting with the trunk line at both ends. Sullivan Square and Dudley St. terminals were designed as elaborate transfer stations, providing for same-level transfer between rapid transit

trains and surface cars, and reversing loops for trains. A number of new surface car routes were established to operate between these terminals and outlying residential districts. Ten intermediate elevated stations were provided, with an additional six stations used as part of the Tremont subway operation.

In 1908 operation through the Tremont subway was given up, and in its place trains used the new Washington St. Tunnel. Four new stations replaced six stations on the Tremont route.

The following year an extension of the elevated structure was completed between Dudley St. and Forest Hills.

In 1919 the first section of a proposed extension to Everett and Malden was completed, consisting of an elevated structure over the Mystic River leading to a temporary ground level transfer station in the Hendersonville section of Everett. In 1938, operation via Atlantic Avenue was discontinued and most of the elevated structure on that line was removed.

MAIN LINE - ROLLING STOCK

The equipment for the original elevated consisted of 150 wooden cars. In general, they resembled contemporary cars in New York and Chicago, with open end platforms and clerestory roofs, but were fitted with one sliding door in the center of each side. Passenger capacities were 48 seats and 162 total, although the capacity for scheduling purposes was 125. Overall length was 46'7", and width at floor level was 8'7 3/8".

Continually increasing traffic brought about the purchase of additional cars of the same general appearance. Twenty-five wooden cars were followed by 120 semi-steel cars, and then by 107 all steel cars, with the total number of cars on the line reaching 402 in 1921. Closed end platforms were introduced in 1904, and the older cars were rebuilt with same by 1906.

In 1927 and 1928 one hundred all steel car bodies were acquired. Fleet size declined gradually to 273 at the end of World War II. In 1957-1958 a series of 100 modern cars were acquired, 55 feet in length overall, with curved sides and three double doors spaced along the car sides.

All cars had four 100 horsepower motors, improved control and braking, and were designed to operate in two car sets. Seating capacity was 48 and maximum capacity was 227, with a schedule capacity of 175. During the following four years all pre-war cars were removed from revenue service. A short table of equipment follows:

175 Narrow Vestibule Wooden Cars in Service	1901 - 1928
120 Narrow Vestibule Semi-Steel Cars	1906 - 1948
207 Wide Vestibule Steel Cars	1917 - 1962
100 Four Motor 55' Steel Cars	1957 - present
602 cars total	

MAIN LINE ELEVATED - OPERATION

During the early years of operation on this line, a number of routing combinations were tried. The basic combination was Sullivan - Tremont - Dudley (later replaced by Sullivan - Washington - Dudley) with a North and South Station shuttle via Atlantic Ave. Additional through services were operated via Atlantic Ave. in rush hours. The through service was extended from Dudley to Forest Hills, and from Sullivan to Everett as these extensions were opened.

When the line opened, the longest trains were three cars in length. Successively, four and five car trains were operated in peak periods, the latter being the longest which could be accommodated in the Tremont St. subway. The Washington St. Tunnel stations were built to accommodate eight car trains, and upon opening of this route, six car trains were operated initially. Simultaneously, all of the elevated stations were lengthened to accommodate eight cars, some stations being extensively rebuilt. The increase to eight car peak period trains came in 1916, 15 years after the opening of the original line.

With the decline in business during the Depression, the maximum train length became six cars, with four cars operated in the off-peak. With the introduction of the first fifty-five foot cars in 1957, six car peak period trains of both old and new types were operated, necessitating the rehabilitation of sliding platforms at Dudley and Sullivan. After the second series of longer cars were placed in service, maximum train length became four cars. At the present time, off peak trains are normally two cars except

during sports events and during the Christmas shopping season.

It appears that the maximum number of trains operated in each direction between Sullivan and Dudley never exceeded 32 in one hour, although it was regular practice to schedule 1-1/2 minute headways over the various segments of the line. Color light signals installed to replace semaphore type in 1921-24 permitted a one minute headway to be operated, but station time and junction movements did not permit such a headway to be scheduled. In certain locations where delays were most likely to occur, additional signals were installed to permit following trains to close in.

In the Fall of 1910, all six-car trains were operated in the peak, 22 per hour in each direction from Sullivan to Dudley via Washington, and 10 additional between the same terminals via Atlantic Ave., resulting in flows of 22 trains with 132 cars per hour in the tunnel, and 32 trains with 192 cars on the north and south legs. In the fall of 1917 the peak rates in the tunnel were 21 trains and 168 cars, and the flows on the north and south legs were 29 trains and 252 cars. By 1938 the rates had declined to 24 trains and 144 cars per hour in the tunnel, and 31-1/2 trains and 159 cars in the Tower D to Dudley Section. At the present time, using 55' cars exclusively, the rates in the tunnel are 17 trains and 69 cars per hour.

EAST BOSTON TUNNEL (BLUE LINE) - CONSTRUCTION

This facility was originally constructed as a high speed route for streetcars from the East Boston and Chelsea districts underneath Boston Harbor to three stations in the downtown section. It was first opened in 1904. Cars terminated at the Boston end in a single track substation under Court St. at the same level as and directly abutting the Scollay Sq. station of the Tremont St. subway.

An extension of the tunnel was constructed in 1917, when the Court st. station was abandoned, a new island platform station was built under the southbound platforms of the Tremont St. subway Scollay Sq. station, and an extension constructed to a station in Bowdoin Sq.,with a reversing loop, and an incline into Cambridge St.

In 1924, the tunnel was converted from surface car to rapid transit train operation. This involved the construction of an underground transfer station at Maverick Square, with the tunnel tracks spreading apart and leveling into the platforms, and continuing into a short radius reversing loop beyond. The two tracks from the original surface incline occupied the center of the station, and terminated in a tight reversing loop. In addition, all other tunnel stations had to be fitted with high platforms. The actual changeover from one service to another was accomplished over a three day weekend.

In 1952 a surface extension of the tunnel was opened to Orient Heights, continuing north of Maverick via the former inspection pits and a surface incline along a new right-of-way to the terminal. A large storage yard and repair shop was provided nearby. A further extension along the railroad right-of-way was completed in 1954, terminating adjacent to the Wonderland Race Track in Revere.

EAST BOSTON TUNNEL - ROLLING STOCK

The vehicles in use on the company's surface lines at the time this tunnel was opened were of the small double truck variety, and the development of streetcars is outlined in detail in the Central Subway rolling stock discussion. It was the practice of the company to use its newest surface cars in tunnel service, and the Type 1 and then Type 2 cars were assigned. Some experimental multiple unit operation was done with Type 2 cars in the tunnel, but the first series of center entrance motor cars were assigned here starting in 1917 and two car trains were common until conversion in 1924.

The steep grades of the tunnel were hard on the rolling stock, especially when loaded cars were forced to stop and restart in between stations. The four motor C.E. cars were most suitable for this type of service, and in addition the ease of ingress and egress was a benefit at stations. When the increasing traffic through the tunnel brought about the need for rapid transit service, an attempt was made to design rolling stock with similar operating characteristics. The forty-eight cars ultimately acquired were considerably different from any other rapid transit cars owned by the Elevated, but successfully meet the needs of tunnel service.

The fleet of rapid transit cars operated the service under difficult operating conditions without incident from 1924 to 1952, at which time the opening of the surface extensions brought about the need for additional cars. Forty vehicles of modern design were acquired, of similar overall arrangement to the 1924 cars, but incorporating current technology. The older cars were completely rehabilitated, and both series are presently in service on this route.

EAST BOSTON TUNNEL - OPERATION

As this line was originally operated by surface cars, it shared many of the features of Tremont Subway operation, although the density of traffic was not as great. A number of lines, using older cars operating singly, fed into the tunnel and operated to Court St. The single track stub at the latter terminal was a definite restriction on the capacity of the tunnel, but it does not appear that a second reversing track was ever added. As noted earlier, multiple car operation was introduced at an early date and this would have permitted longer headways. In 1906, when single cars only were used, the peak hour flow was 48 cars per hour in each direction, which would have moved easily in the tunnel as a whole, but sharp work was required to reverse at Court St. When the extension to Bowdoin was started, all service was terminated at Devonshire, and a scissors crossover was used to reverse cars on both station tracks. After the extension was opened, the loop at Bowdoin permitted unrestricted movement up to capacity imposed by station time. A 1917 analysis indicates that peak train movements were 42 per hour in each direction, of which 34 were routes to East Boston and Chelsea terminals, while 8 trips were run between Kendall Sq. and Scollay Sq., reversing on a long crossover on the Devonshire side of the station.

In subsequent years a general increase in traffic brought about considerably increased car and train movements. As several destinations were reached by outbound trains, waiting passengers at downtown stations caused considerable congestion on platforms. In order to cope with the business, the Elevated developed a plan whereby service between Bowdoin and Maverick would be provided by high floor shuttle trains, and a large transfer station would be provided at Maverick for transfer to surface cars. This plan was put into effect in 1924. In 1928 the peak hour rate in the tunnel was 24 trains per hour and 96 cars per hour. At Maverick station the surface car flow was 73 units and 117 cars in the maximum hour.

Because of national economic conditions, riding dropped off in succeeding years. In 1934 the train service was a 3-1/2 minute headway (17 + trains per hour) with 4 car trains. Surface connections were at the rate of 49 trains and 79 cars per hour. By 1937, multiple unit surface operation had been discontinued, and 84 single cars were operated from the surface in the maximum hour.

With the opening of the extension to Orient Heights, all scheduled service was extended to this point, and the reversing loop at Maverick was removed. A number of surface lines which had formerly connected with the rapid transit at Maverick were rerouted to feed stations along the extension, and streetcar operation was given up and trackless trolleys introduced. A single track extension to Suffolk Downs station permitted special service during the horse racing season.

Upon further extension to Wonderland, approximately half of the peak hour service ran through from Bowdoin to Revere, with remaining trips terminating at Orient Heights. In base periods all service operates to Wonderland. It might be noted that the turnback facility north of Wonderland is arranged as an automatic interlocking, with trains being routed in and out of turnback tracks in order of outbound arrival.

At the present time, peak hour service on this line is operated with four car trains at maximum rates of 20 trains and 60 cars per hour.

CAMBRIDGE SUBWAY (RED LINE) - CONSTRUCTION

The first section of this route to be opened for travel was the segment from Harvard Square to Park Street in 1912. The line was entirely in subway except for the crossing of the Charles River where the tracks were in reservation in the center of the West Boston Bridge, with a short section of elevated structure on the Boston side.

This subway was extended in stages through downtown Boston and South Boston, reaching a terminus at Andrew Square in 1918.

Several plans for extension of this line were evaluated in the following years, and construction was finally undertaken using a portion of the surface right-of-way of the Old Colony Railroad's main line and Shawmut and Mattapan branches. Train service was extended to Fields Corner in 1927, and to Ashmont the following year. The portion of the railroad right-of-way between Ashmont and Mattapan was rebuilt for use as a high speed surface car line.

CAMBRIDGE SUBWAY - ROLLING STOCK

Cars acquired for service on the initial Park Street to Harvard segment were designed to make maximum use of the clearances of the subway, and were much larger than any other equipment on the property. Generally similar to the contemporary vehicles on the new Fourth Avenue subway in Brooklyn, they were nearly seventy feet long and nine and a half feet wide. Seating capacity was 72 and maximum capacity was 285 passengers.

Sixty cars in two batches were bought for use on the initial segment, and another 40 cars were purchased to provide service on the extensions into South Boston. With the opening of the extensions at Ashmont a further sixty cars were acquired.

After World War II, when an extension to points on the South Shore was being studied, a four-car train of the newest cars was extensively modernized with cushioned cross seats, fluorescent lighting, and ventilation fans.

Although 20 of the oldest cars were removed from service at an earlier date, the remaining 135 cars continued in service until 1963, when all were removed from service and replaced by 92 new vehicles. These cars were of similar dimensions to the older stock, but were provided with curved sides above platform level to increase interior capacity. The door arrangement was like that of the Independent subway cars in New York, with four double-leaf sliding doors along the length of the car side.

An additional 76 cars were received in 1969 for use on the South Shore extension, and have been used in the Harvard-Ashmont service. Although nearly identical in overall dimensions to the 1963 vehicles, they have only three doors per side, air-conditioning, fluorescent lighting, and most seats are of the two-passenger transverse type with upholstered cushions and backs.

CAMBRIDGE SUBWAY - OPERATIONS

From the initial opening of service down to the present time, the operations on this route have changed very little. Peak hour service was provided by four-car trains operating at a minimum headway of two minutes, with mid-day and evening service operated with two-car trains at a four to six minute interval. Changes in traffic levels were accommodated by altering the headways, with a minimum and maximum peak headways of one and three quarter, and three and one-half minutes, respectively.

For a time between World War I and II, mid-day service was provided by three-car trains operated by two men, but when the guard

law was enacted two-car base operation was resumed.* At the present time four-car trains are operated in the peak periods at a maximum hourly rate of 19 trains in each direction, and mid-day service uses two-car trains on a six-minute headway.

SUBWAY FLOW AND CAPACITY

Considering a single track of railway line, operated in one direction only, a maximum rate of flow may be established. This maximum rate is subject to certain stipulations, such as optimum speed over the section under study, including the effects of grades, curves, signals, and stations. It is also assumed that there is an adequate supply of vehicles into the section under examination, and that there is sufficient outlet to the section. The maximum rate will require a certain average speed of each vehicle. If the rate of flow is less than the maximum, higher running and average speeds will result, and conversely if the maximum practical rate is exceeded extremely low average speeds will result. The capacity quoted earlier in this chapter of 240 cars per track per hour in the Central Subway was based on two factors: (1) No signal system, with operating under surface rules, prepared to stop within sight, and (2) All cars are single units. The resultant average speed including station stops was 7.5 miles per hour.

If a line of cars is operating at a rate of, for example, 60 cars per hour in the subway, and it is desired to divert half of these cars onto a parallel track, the resultant rates of flow beyond the diversion point would be 30 cars per hour on each track. If the parallel track had no cars scheduled before the point of diversion, it would have a flow of 30 cars beyond it. However, if the parallel track carried initially 60 cars per hour, beyond the diversion point it would carry 90 cars. Additionally, if it is desired to route half of the original 60 cars on the parallel track to the first mentioned track, a net flow of 60 cars per hour on each track beyond the diversion point would result. However, if these crossings are to be made by simple connecting tracks, without grade separation, additional consideration must be made of the effect of the crossing movements. If a car arrives at the crossover point on track 1, and

*The guard law, Section 91A of Chapter 161 of the General Laws, which is applicable to street railway companies and the MBTA, reads as follows: "Section 91A. - Every company shall, during the operation by it of any passenger train consisting of more than one guard, or employee having similar duties, for every two cars of such train....."

is scheduled to continue onward via parallel track 3, the move can be made most efficiently if there is no car passing or approaching on track 3, and the car can then pass through the crossover at maximum permissible speed. In other words, the car occupies two spaces or paths, one space on track 1 by which it approached the crossover, and an additional space on track 3 by which it leaves the crossover point. Another way to see this is to consider what happens if the car approaches on track 1 and finds track 3 occupied by a continuous stream of cars. It must then wait on track 1, delaying following cars, until there is a break in the flow on track 3 when the crossover movement may be made. What this analysis tells us is that if a series of routings of this type is planned, sufficient space must be left on both operating tracks for each car scheduled to cross. If we go back to the example where we have 60 cars per hour approaching on each track, and it is desired to cross half of each flow to the other track, we must calculate as follows:

> Track 1, 30 cars through + 30 cars 1 to 3 track + 30 cars 3 to 1 track = 90 cars per hour.

The analysis for track 3 is similar with identical results. From this we see that with 50% crossing movements, total track occupancy increases by 50% over input volumes.

If we go back to the 1917 analysis (Page 6-9) and designate the northbound track from the Boylston Street subway to Park Street loop as track 1, and the parallel track from Pleasant Street to Scollay Square as track 3, the calculation proceeds as follows:

> Track 1, (85 units from Boylston Street) 71 units through to loop + 14 units track 1 to 3 + 21 units track 3 to 1 = 106 units per hour.
>
> Track 3, (50 units from Pleasant Street) 29 units through to Scollay + 21 units track 3 to 1 + 14 units track 1 to 3 = 64 units per hour.
>
> Apparent total volume northbound: 85 units track 1 + 50 units track 3 + 135 units per hour.
>
> Actual occupancy northbound: 106 units track 1 + 64 units track 3 = 170 units per hour.

Thus, although the peak load point in terms of actual units was 92 per hour through the Park Street loop, track 1 must accommodate 106 units per hour. The foregoing analysis also applies to intersecting movements, such as where a southbound car must cross the path of a northbound car, and sufficient car space or paths must be scheduled to permit free movement. Where it might have been possible to arrange routings in the same direction to be parallel but non-intersecting, as was the case with the initial operation of the Boylston-Park segment of the subway, if we are given a track layout where intersecting movements must be made, we have an immediate and severe restriction on capacity. At the time of the 1919 analysis, the only points where intersecting moves were made was in the Canal Street loop where northbound cars entering the loop crossed southbound cars from Charlestown. However, as only 16 units per hour arrived from Charlestown and 24 units entered the loop, the effect of conflicts would have been minor.

The foregoing discussion relates generally to both operations in the Central Subway, where units arrive erratically, as well as to rapid transit lines, where it is possible to schedule and operate movements at junctions, etc., more precisely. The term "erratically" is used for two reasons; to indicate that vehicles coming from points on the surface arrive at the subway less precisely on schedule than does a rapid transit train from an outer terminal, and also to indicate that because of the large number of units operated it is impossible to designate practically the order and exact time of arrival of surface units. While it is difficult to arrange for the 7:40 A.M. inbound cars from Lake Street to pass through Copley Junction directly ahead of the 8:05 outbound car to Huntington Avenue, it is possible to predict the number of units making the various moves and allow sufficient paths so that moves can be made with a minimum of delay.

SURFACE LINES - DEVELOPMENT

Local public transportation began operation early in the 19th century in the form of horse drawn omnibuses operating between downtown Boston and important suburban districts. The capacity of these vehicles was limited, and speeds were slow on account of the poor roads of the time. Steam railroads were constructed starting in 1836 and carried passengers from Boston terminals to more distant points at higher speeds than was possible on local roads. The railway concept was introduced to local surface transport in 1856 with the building of the first horse railroad. These vehicles provided greater capacity and speed than the omnibuses, and their adoption coincided with a general increase in travel on account of industrial development, and construction of additional lines was undertaken rapidly by several companies.

The basic form of the surface transit system as we know it today began to emerge with most major radial highways and many lesser radials and crosstown routes being served by car lines. The introduction of electric motive power starting in 1889 brought about a great increase in speed and capacity, and permitted residential development in sections of Boston and surrounding communities which heretofore had been too remote in terms of travel time to permit convenient commuting by surface vehicles. In the meantime, traffic on steam railroads had grown considerably, and those who could afford the higher railroad fares were using this means to travel to and from more distant points each day. The adoption of electric traction on the street railways permitted competitive travel times to steam railroads in several outlying districts, and resulted in a large number of former railroad users to patronize the streetcars. Continued growth of the metropolitan area into the present century brought about more street railway extensions, and the travel on steam railroads again began to grow, bringing people from more distant communities. In addition, many of the districts closer to downtown Boston which had formerly been relatively lightly developed began to increase in density, resulting in further street railway traffic.

In 1891 the population of the metropolitan area was 850,000 and annual travel on the street railways was 136 million journeys, with the steam railroads carrying 51 million.

Up to 1897 all street railway routes in greater Boston of a radial nature operated from suburban districts through appropriate roads into the downtown section, and a number of these lines even with electric cars required long journeys in both distance and time.

In addition, congestion in the downtown area was beginning to develop with cars from all sections of the area letting off and picking up passengers. The geography of downtown Boston with its narrow streets and compact business district caused this problem to become acute here much earlier than it did in other cities. The surface network as we know it today is remarkably similar to that existing before the turn of the century. The exceptions occurred primarily in the downtown area, where many streets had surface trackage where routes from the suburbs operated, providing terminal distribution and collection.

The opening of the Tremont Street subway relieved much of the congestion along that artery resulting in improved operating speeds, but the existence of long radial surface lines was unchanged. It was not until the opening first of the elevated

line in 1901 and other rapid transit lines later that the surface routing pattern began to change. These new rail lines began to relieve the surface network of the long haul function, but as virtually all of the streets served continued to require local transportation, the change was one of density rather than one of pattern. However, the introduction of rapid transit operations, permitting commutation over a much greater distance for the same total travel time as previously, resulted in further development of outlying sections of the central area, and existing surface routes in those districts began to increase in density to correspond with the decreased passenger miles on closer-in surface lines. Some new surface lines were opened in this century, but the increase in surface route miles was not nearly as extensive as in other American cities. A high of 381 million revenue passengers occurred in 1917.

Coming into the 1920's, the surface line trackage began to decrease on two accounts: Lightly used rail lines were converted to shuttle motor bus operation, and downtown trackage was rationalized as through surface routes were eliminated. Simultaneously, the introduction of streetcar train operation permitted the development of high capacity service on trunk lines, and less important routings using existing trackage were discontinued.

Increased labor costs coupled with a decline in riding due to national conditions in the late twenties and early thirties, with a low of 268 million passengers in 1933, brought about more extensive conversions to motor bus operation and some complete service abandonments. In the late thirties the development of the electric bus, or trackless trolley, permitted abandonment of deteriorating surface trackage and vehicles while retaining the efficiency of electric motive power. These vehicles outstripped the motor buses of the time in carrying capacity and reduced operating costs, and many heavy surface lines were converted for trackless operation.

All forms of transport in use at the start of World War II were subjected to a great increase in traffic on account of the reduced use of the private automobile and heavy travel to military installations and manufacturing plants. Large numbers of street and rapid transit cars were removed from storage to handle the business, and many vehicles of all types were kept in service well after their natural life expectancy. The highest annual riding in system history occurred in 1946 with 433 million passengers.

With the return to peace, the heavy traffic on the transportation system declined somewhat, and then began to fall rapidly with the

greatly increased use of private autos. By 1960 the annual volume was 200 million passengers. Some service extensions were made to new residential developments, and routing changes were made to accommodate highway construction, but the network changed but little. The operation of street railway vehicles was sharply curtailed and motor buses and trackless trolleys were acquired in increasing numbers. In several cases, conversions to rubber tired vehicles resulted in division of former through routes, particularly those serving the central area. The East Boston and Revere rapid transit extensions resulted in a whole new trackless trolley division, routed to serve the various new stations, over thoroughfares formerly served by streetcars.

In the most recent period, rail service was extended over the B&A Highland Branch serving an area which was outside the former Boston Elevated district, and was covered by a private bus carrier whose business had drastically declined in the post-war years. All remaining car lines not serving the Central Subway, excepting the Mattapan-Ashmont shuttle, were converted to bus operation, and most of the trackless trolley routes were likewise motorized. With the formation of the MBTA, and the acquisition of the Eastern Massachusetts Street Railway's bus routes to the north and south of Boston, the surface network changed very little. Some new services were instituted, and others were rearranged, but in comparison to the total operation the changes are small. Private bus carriers continue to exist, but in common with the Authority the level of traffic is declining and services are reduced accordingly. In 1969 the Authority traffic was 153 million (excluding Eastern Massachusetts lines), down 24% from 1960, down 65% from the 1946 high and only 11% above the 1891 traffic.

The construction of rapid transit extensions to the north and south of Boston promises to reduce travel time and improve comfort with a corresponding increase in ridership. Changes currently planned in surface lines to feed these extensions concentrate on rerouting services over thoroughfares presently receiving local transportation.

SURFACE LINES - ROLLING STOCK

In the section on the Central Subway, a summary of the surface rail cars used by the company was given. It was noted that the maximum inventory of such vehicles was 3,396 in the year 1915. Motor buses were first used in 1922, and electric buses were introduced in 1936. The early buses were of small capacity, with gas engines and mechanical transmissions. Improvements through the years included larger bodies of integral construction

and more efficient engines and transmissions. Just before World War II the diesel engine and the automatic transmission were developed for bus use, and permitted larger, more reliable vehicles. At that time the largest production vehicles had a nominal seating capacity of 45. In the ensuing years bus development has continued along these lines. At the present time there are only two major manufacturers, and the typical product is a 53-passenger diesel-hydraulic coach. Although there have been many styling changes, the basic body layout is very similar to that of the pre-war models. On this property, the number of vehicles gradually rose from zero in 1921 to just over 600 in World War II, remained relatively constant until 1960, and then began to climb account retirement of vehicles of other types, and acquisition of the Eastern Massachusetts Street Railway fleet. As of July 1, 1970, there were 1,311 buses on the property, including 51 leased to the Middlesex & Boston Street Railway and 10 leased from private carriers.

Of the 1,301 buses which the Authority owns, 812 are of nominal 49 to 53 seat capacity, 379 are in the 45-47 seat range, and 110 are 40 seat and smaller types. It might be noted that for a number of years this company has fitted buses of a certain nominal capacity with a lesser number of seats to provide for greater standing capacity. A typical bus of the 53-seat type actually seats only 45. Another unusual feature is the use of double width rear doors on any buses. This feature permitted somewhat better passenger handling characteristics at rapid transit terminals without altering the manufacturer's basic design. In the latest orders this feature has not been included.

With respect to age, 726 buses, or 56% of the fleet is of the "new look" type, acquired since 1959. Four hundred of this group are fitted with air-conditioning.

Electric coaches were first used in 1936 in Cambridge, and their use was expanded rapidly until 1953 in which year a peak of 443 coaches were on the property, in comparison to 543 buses and 507 surface cars in the same year. These vehicles permitted replacement of deteriorated surface cars and trackage while continuing to use electric power, and they were applied principally as streetcar replacements, with a small number of line extensions or reroutings. In comparison with pre-war buses they were exceptionally efficient, but improvements in postwar buses reduced this advantage. The last vehicles of this type were as large as the newest buses, and all doors were of the double width type. A number were fitted with left-hand doors and this group of 60 now constitutes the entire roster of trackless trolleys, assigned to routes using the Harvard Square subway.

SURFACE LINES - OPERATION

In the early years of surface operations, it has been noted that there was a great deal of trunk line operation. Various surface lines originating at scattered outlying terminals ran together on main streets for considerable distances into the downtown area, performing a line haul function as well as collection and distribution. As cars operating on a trunk line came from more than one division in a number of cases, they were separately subject to the direction of supervisors from their home divisions while enroute, and they were additionally subject to supervisors of Division 8 while in the downtown area. The effect of this system was to make the various trunk line tracks "common user" operation. As the cars did local work as well as line haul, erratic operation resulted in uneven passenger loadings and increased running times despite the quantity of service. The repercussions of this irregularity were strongly felt in the outlying areas, where only one line operated.

As rapid transit operations were extended on the various lines, surface lines were rearranged to feed these new services. The train service took over the line haul function, and the surface lines collected passengers in residential areas and delivered them to the rapid transit. Joint operations by several lines over the same streets still existed, but such cases were generally within the limits of a single division, and round trip running times were much less, resulting in a general improvement in service. A number of streets in the closer-in areas which formerly were served by lines from outer districts were now accommodated by lines run to serve their local demands solely, and headways were considerably longer than previously.

Boston was one of the few cities where coordinated surface and rapid transit operations were undertaken from the earliest years. It has been remarked that the main line elevated provided for elaborate transfer stations, and through rides for one fare were universal. In later years, when the base fare had risen to 10 cents, a local fare of 5 cents was instituted for journeys confined strictly to one surface line. This general fare scheme continued in effect until 1961, when transfers were eliminated and separate fares were instituted for each line used. The scheme of a flat fare for through rides permitted a number of service improvements which were uncommon in other cities. One such arrangement was the collection of through fares in rapid transit stations from arriving surface line passengers resulting in improved surface running times.

The coordinated operation included not only a single fare, but also easy transfer movements by means of off-street loading and

unloading areas for surface vehicles, a number of them on the same level as rapid transit vehicles, providing a true "across-the-platform" transfer, as at Field's Corner. In cases where the transfer was not as convenient, it often provided for under-cover movement with escalators for changes in the vertical direction, such as at Andrew Square.

Where secondary streetcar lines were replaced by motor buses in the earlier years, it was common for the motor bus to operate to and from a connecting car line rather than through a rapid transit station or to downtown. This practice became especially prevalent as certain car lines were rearranged for train operation and parallel routes were converted. The through fare scheme applied and patrons were only subject to an additional transfer. As buses became more reliable and were produced in larger sizes, some heavy car lines were converted in their entirety, the Allston-Dudley line being a good example. At about this time, however, the trackless trolley was becoming popular on a national basis and was introduced in Boston and was rapidly assigned to complete conversions of streetcar lines. Transfer stations which had been built for streetcar operations, and in some cases had busways attached, were paved for rubber-tired operations. Former shuttle bus lines were gradually extended into these terminals, although a few exceptions persisted.

With the decline in traffic in the thirties, several secondary lines, particularly in the districts close to downtown, were reduced to minimal service or abandoned entirely. Some new lines were started to service functions which had not been previously accommodated. One example is three routes to downtown areas from the East Boston Airport which have since been discontinued.

Coincident with the conversion of lines from streetcar operation to bus or trackless trolley operation, the reduced capacity of the newer vehicles has often resulted in a shorter headway being scheduled to accommodate the same traffic, and this service improvement has brought about some increases in riding apart from the marketing value of new vehicles.

With the general increase in labor costs over the years the trend has been towards a reduction in the number of supervisory personnel on the street regulating the service. Those men who are now assigned to regulate surface lines away from carhouses and rapid transit stations travel in radio-equipped automobiles. Boston had never achieved the level of mechanized control over surface operations that some other properties did, Pittsburgh being a good example of the latter. Most local routes either passed a carhouse enroute or entered a rapid transit terminal

and manual supervision was concentrated at these points. Some street men are still used at key loading points, but for the majority of the operating day supervision is provided by a small number of men in automobiles.

It was noted in the section on capacity in the Central Subway that the maximum volume on a surface car line operating in mixed traffic was 160 single cars per hour. This level was reached only on trunk line operations and at subway entrances. With the expansion of rapid transit lines, the level of services on individual streets declined markedly. In some cases, such as the east approach to Dudley Station, the surface movements were large in number, but there were relatively few such locations about the city. Train operation on busy surface lines further reduced the number of surface movements.

Since World War II the general level of surface operations in terms of headways has declined considerably, reflecting not only decreased riding but increased labor costs. At the present time there are few locations where a peak period headway of 3 minutes or less is offered, and several of these cases involve "trunk line" operation by multiple routes. A five-minute or better headway is run on a good proportion of the system, but there are many sections which have only ten or fifteen-minute intervals at best. It might be noted that all surface lines are operated with one unit on each trip excepting the Central Subway feeders which are served by streetcars operating in trains. Commonwealth Avenue is scheduled for three-car trains at three-minute intervals resulting in 60 units per hour, which makes it the busiest surface line on the system, with the Huntington Avenue and Beacon Street lines falling in behind at 46 and 40 cars per hour, respectively. The heaviest single bus line in the system is the Arlington Heights Limited with 30 buses per hour. An additional 30 vehicles per hour operate local south of North Cambridge carhouse, providing 60 vehicles per hour on that section of Massachusetts Avenue. The 30 local vehicles are divided 15 each to Watertown and Waverly, and are operated by trackless trolleys. The second busiest single line is the Allston-Dudley route with 20 vehicles on variations for a total of 37 trips. A heavy surface section is Centre Street and Belgrade Avenue in West Roxbury with a 2.5 minute peak headway, merging with additional lines north of Roslindale Square to produce a flow on Washington Street of nine routes and 60 vehicles per hour.

In several cases heavy surface line operations are scheduled to be supplanted by rapid transit extensions, with the latter taking over the line haul work and returning the surface lines to the status of short collector-feeder routes.

SOME PROBLEM AREAS IN TODAY'S MBTA SYSTEM

Central Subway and Surface Feeders

It has been noted that in the past the Boston Elevated gradually reduced the complexity of its surface operations by developing surface rail trunk lines using two and three-car trains. In many cases the routes concerned were rapid transit feeders, but several were through operations into the Central Subway. In particular, the late development of Brookline and Brighton in comparison to other areas equidistant from downtown Boston resulted in two factors: the development of extensive center reservations for car operation, and the lack of older, high-density districts as prime candidates for heavy rapid transit service. Other reservations did exist in Boston, but the combination of factors applying to these lines was not the same. The Fellsway route was largely in reservation, and that area developed only in recent years, but through service to downtown had not existed since 1901. Blue Hill Avenue featured a long reservation but the line had fed the Elevated since 1901 and was paralleled by the Elevated and the Dorchester Extension.

Other lines which fed the Central Subway served separate functions with different characteristics: The Broadway and Tremont Street lines were exclusively street running and ran in close proximity to rapid transit lines serving older, closer-in residential districts. The Charlestown lines ran through congested areas and served short haul traffic. The Somerville lines were longer street-running lines with a good off-street run from East Cambridge, but they were divided in 1922 when through service was discontinued.

The development and decline of traffic through the years caused the attrition of nearly all the street-running feeders to the subway with four lines remaining, all with some sections of center reservation, and served in peak hours by multiple unit trains. The Highland Branch (Riverside Line) was added in 1959 and operates completely on private right-of-way with no interference from other traffic. These various changes reduced the formerly complex Central Subway operation to a relatively simple double track trunk line with merging lines on its western section and several turn-back facilities in the central and northern parts. Considering the subway portion alone, the operation of four or five lines on a private right-of-way rail facility is somewhat unusual but certainly not the only such case.

Several examples exist in rapid transit practice where trains on several services occupy the same trunk line trackage. Most of

these cases are based on the use of six to eleven-car trains operating on an integrated schedule with headway arranged to permit station occupancy by one train at a time. The Central Subway in the past has worked on the principle of several lines on separate schedules with short trains and multiple station occupancy. Systems of berthing trains at stations have merit in reducing excess passenger movement along platforms, but trains must be run in a predetermined order to make it really effective. In most cases in our subway, and in other facilities operated in the same manner, passengers are left to fend for themselves in watching approaching trains and situating themselves accordingly on the platform.

One approach to Central Subway problems would be to evaluate in detail the requirements of the various lines and to develop an integrated schedule providing for movement through the subway in a predetermined order by route. A second aspect is to improve information given to patrons with regards to approaching trains. Current technology should permit an automatic destination and berth display at a fraction of the cost of earlier methods with much greater efficiency. A third area which should be investigated is the feasibility of longer trains, permitting a longer subway headway with single station occupancy. Two methods which would permit this is the running of longer trains at longer headways on surface feeders, or running short trains on the surface to be made up with other trains at subway portals. In the discussion of Central Subway capacity earlier in this chapter, it was noted that the present flow rate is 66 units and 164 cars per hour, with maximum train length of three cars, giving a net average headway of 54.5 seconds. If an actual headway of one minute were to be run with four-car trains, the peak rate would increase to 60 units and 240 cars per hour. Minimum platform lengths would permit six-car trains, resulting in a capacity of 360 cars per hour, without major reconstruction. Although traffic demands on all lines are not equal, the six-car possibility would permit accommodation of greatly increased traffic on one or more lines without embarrassment.

One point in the Central Subway which requires further evaluation is the junction of the Huntington Avenue subway at Copley. The capacity problem here was discussed earlier, and possible remedies are discussed in later chapters and in Volume II. Another difficulty which should be remedied is the number of scheduled terminal points, especially those without layover capability. Although emergency reversal facilities are desirable, it would be in the interest of greater schedule reliability to schedule only such turnbacks as can permit waiting time, thereby reducing the spread

of delays from inbound to outbound half trips, and also reducing transfer movements in the subway between one line and another operating in the same direction.

The aspects of the operation of Central Subway routes on the surface merits a separate discussion as the problems are of a somewhat different nature. The principal sources of time consumption enroute on a surface line are the time required to cover the distance from starting point to portal, the time additionally needed while running on account of traffic signals and interference from other vehicles, and the time at stops to load passengers and to collect fares. In terms of the lines in questions, the principal source of irregularity and potential time saving is the second factor, additional time because of outside interference. The lines with street running (i.e., without a median strip) suffer the most from this problem, and although some improvements can be achieved at individual locations, the basic conflicts between streetcars and motor cannot be avoided on such lines.

A general problem which applies to Central Subway and feeder line operations equally is the problem of effective supervision of the services. While it is true that the operation of several separate surface lines into a common subway poses a number of operational problems, this Authority has had long experience with the operation, and techniques and hardware are now available to permit more effective control of this operation.

Rapid Transit Lines

A brief history of operations on the various rapid transit lines has been given earlier in this chapter. The three lines which exist today are simple double-track lines with a maximum of two routings per line. All are completely grade separated with two of the three lines using postwar rolling stock exclusively. The basic problem with all three lines appears to be the operation of a reliable and regular service. In comparison with other properties, the operations are very simple and the routes not difficult, and it would appear that efficient, on-time services could be easily provided. However, three factors combine to make rapid transit operations in many cases as ineffective as surface lines. One factor is the shortage of serviceable equipment, resulting in schedules being altered to use available cars, and also a high number of in-service failures; a second is lack of sufficient manpower to cover the schedule when men are late or sick; and a third problem is the lack of means for effective supervision to detect service deficiencies and to make changes

promptly. Where a large part of the surface system depends on the rapid transit segments to perform line-haul work, the failure of the latter results in widespread congestion. Affiliated with this problem is the lack of effective means to inform passengers of delays and of alternate routes to destinations.

It might be noted as a general observation that while the rapid transit lines in Boston have all the desirable features of other properties in terms of high platforms and ample doors, too much time is spent in stations, and this factor is often quoted as a reason why shorter headways are not possible. Serious attention should be given to the causes of excess station time, and a program for its reduction instituted. Considering the costs for new rapid transit facilities, it would appear prudent to make the best use possible of the existing plant in order to avoid such capital expenditures.

In terms of modern rapid transit practice, all three of our lines of that type should be capable of operation at ninety-second intervals with the maximum train length permitted by station platforms. Sufficient successful examples exist on other properties to assure us that this goal is attainable when the traffic warrants it, and tried and proven techniques and hardware are available for its achievement. The signal systems on all lines were designed for a free-running frequency of 60 trains per hour, and with proper control, including operation to schedule, and reduction of station time, there appears to be no reason why 40 trains per hour cannot be scheduled. With growth in demand, station platform lengthening can be undertaken, providing additional capacity on existing lines at a fraction of the cost of construction of new lines with like capacity. In addition, the operation of more than one service on each line is easily accomplished and numerous examples can be cited.

Following is the present scheduled peak hour service on each of the lines, accompanied by a calculation of the capacity of each line based on present facilities.

Main Line Elevated - Present Service: 17 trains, 68 cars, 11,900 passengers per hour per direction.

Capacity Service: 40 trains, 240 cars, 42,000 passengers per hour per direction.

East Boston Tunnel	-	Present Service: 20 trains, 80 cars, 10,000 passengers per hour.
		Capacity Service: 40 trains, 160 cars, 20,000 passengers per hour.
		With platform extensions at Aquarium and State only: 40 trains, 240 cars, 30,000 passengers per hour.
Cambridge Subway	-	Present Service: 19 trains, 76 cars, 20,900 passengers per hour.
		Capacity Service: 40 trains, 160 cars, 44,000 passengers per hour.

Totaling all three lines, providing five routes into downtown Boston, peak hour capacity into the downtown area as now operated is 75,600 passengers, while route capacity is 202,000.

Surface Lines

Those routes of the present system which operate entirely on surface roads shared with other traffic suffer delays from all of the sources mentioned in the paragraphs of Central Subway surface feeders. Because they lack a defined right-of-way, these vehicles can move about to avoid stopped vehicles and other obstructions, but the lack of a defined track can cause delay and reduce the benefits of flexibility. A common example of this latter factor is the occupancy by parked cars of a bus stop, resulting in the blocking of a traffic lane while loading passengers.

Problems of this type are common to all bus operators, and the solutions appear to lie in a combination of company training with supervision of its own operators, and improved traffic controls and law enforcement by the municipalities in which the service is operated. Another not uncommon problem is poor scheduling and time-keeping. One of the criteria for developing an efficient operation is to accurately assess the traffic demand and the capabilities of the men and equipment. From this a good schedule must be undertaken. Without proper supervision the characteristics of individual drivers and the general delays caused by auto and riding traffic will cause any line to run off schedule, and it requires an experienced outside observer to know that the service is not running to time and to make the alterations necessary to quickly restore the vehicles to schedule.

Other universal problems are concerned with rolling stock and with routings. In the first case, the industry today is dominated

by one manufacturer who has been able to market a small line of vehicles to many different properties, and especially in the cases of the larger operators the production line product does not always meet local needs. Technological development in the U.S. motor bus industry has lagged in recent years, and many manufacturers offering superior features have discontinued production. A key deficiency is ability to load and unload efficiently, particularly where movement is not restricted by fare collection. A second drawback is the low capacity per crewman. A third problem is the efficiency of the engine and transmission and the maintenance of same, and a fourth is the weakness of construction and difficulty of body repair after accident damage.

Routings are in many cases dictated by historical trends and geographic constraints. Relatively few properties today have a sufficient operations planning force to evaluate existing operations and to plan and institute new services. This area of manpower is one of the first to be reduced when patronage drops and costs rise, and it is unfortunate that such is the case because it is often in the lean times that the most astute management is needed to prevent a gradual decline from developing into a tailspin. Despite today's economics and the competition from the private automobile, bus operators are instituting route changes and extensions and are making them pay. Wherever new development, both residential and commercial, is taking place there is potential for new riders. Where the transit operator is a major metropolitan system, changes in routes have all the more potential for drawing new business.

Individual problems which beset the surface operation on this property in particular are related to the dual-vehicle nature of many passenger journeys. As noted before, this system is built on the concept of rapid transit lines providing line haul service, with surface lines doing collection and distribution work. The problems come when we attempt to provide an average traveler boarding a subway train downtown with a fast, efficient journey to his suburban destination. In peak periods the frequency of service on both rapid transit lines and buses is generally sufficient to make a reasonable connection without a long wait at the transfer point. In off hours the longer headways on surface feeders could mean a long wait for the feeder bus. With the general lengthening of headways on both rapid transit and surface lines in recent years on account of reduced traffic, the problem is aggravated. With the addition of two other factors, surface lines and rapid transit not operating to schedule, and schedules not written to provide easy connections, the whole problem of transferring becomes critical.

A general investigation of transfer practices and possible improvements is in order, with the goal of providing the present and the prospective passenger with a fast, pleasing ride. If the various elements of the surface and rapid transit system are not operating in concert, money being expended in crew's wages is not being used to best advantage in providing service, and in addition, new traffic is being discouraged.

CHAPTER 7

A SOCIO-ECONOMIC ANALYSIS OF THE GREEN-BLUE LINE TERRITORY TODAY

THE STREETCAR-SUBWAY

In preparing the 1966 MBTA Master Plan, the streetcar-subway and the East Boston rapid transit lines were analyzed and found to be in need of improvements, especially the streetcar-subway. The nature and extent of the needed improvements was far from clear, and it was obvious that further study of both lines would be necessary. It was apparent that the deficiencies of the Blue Line were concentrated in downtown Boston, where it provided little distribution of passengers, whereas the difficulties of the Green Line stemmed from an old downtown tunnel handling a great number of varied demands, including collection, line haul and distribution. The focus of study therefore shifted to the problems of the streetcar-subway in downtown Boston, and the relationship of this facility's function to the distributional deficiencies of the Blue Line.

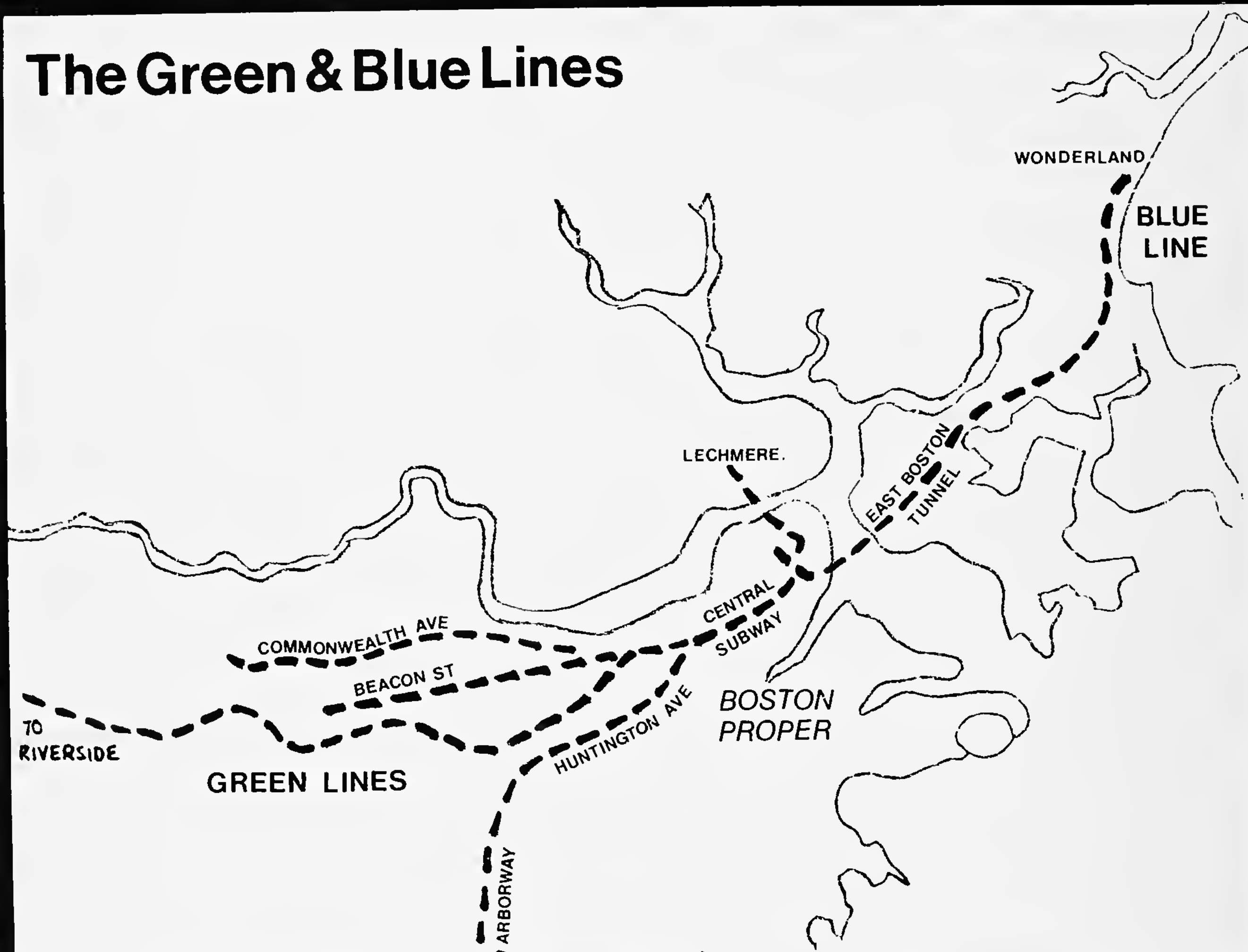
The analysis of streetcar-subway and Blue Line problems pointed out the unique relationship of land uses, population densities and transportation services outside downtown Boston, which is perhaps more evident in the Green Lines than in any other Inner Cities services which the MBTA operates. Because of these unique relationships, it has been the hope of this report that a focus on the Green Line streetcar-subway could provide insights into Inner Cities movement problems and possible solutions which could be transferred into other geographic sub-sections of the Inner Cities. This is not to imply that streetcar services offer a panacea and should be reinstituted in former areas of service; it is, rather, to use this analysis as an impetus to upgrading MBTA services throughout the Inner Cities Area.

In examining the services provided by the Green Line streetcar-subway and the Blue Line, it has been convenient to divide the analysis in halves--the first dealing with downtown distribution, and the second covering ridership characteristics, particularly in the geographic areas outside downtown.

DOWNTOWN DISTRIBUTION

The historical development of the Green and Blue Lines has focussed on downtown Boston. Figure 7-1 indicates the relationship of the

Green Lines and the Blue Line East Boston Tunnel to Boston Proper. Boston Proper as a definition of downtown Boston or the Central Area has been used in most transportation studies of the region as a standard geographic designation of the core of the region.



(FIGURE 7-1)

In 1963, Boston Proper was the location of about 245,000 jobs. At this time the Authority's role was to carry about 156,000 people across the cordon line defining downtown Boston and to deliver them to downtown locations. Presumably the Authority also transported these patrons on the return portion of their round trip, making a daily total of 312,000 revenue trips per weekday of the corridor-to-downtown category. Approximately 24,000 additional revenue trips were estimated by the consultant which utilized transit for intra-downtown trips.

The extensions underway as part of the Authority's Master Plan will have an immediate impact on the number of patrons carried to the Central Business District. With the Orange Line extended north to Oak Grove and south as planned, and the Red Line extended to South Braintree, and with the Central Business District retaining the base employment population, the Authority would

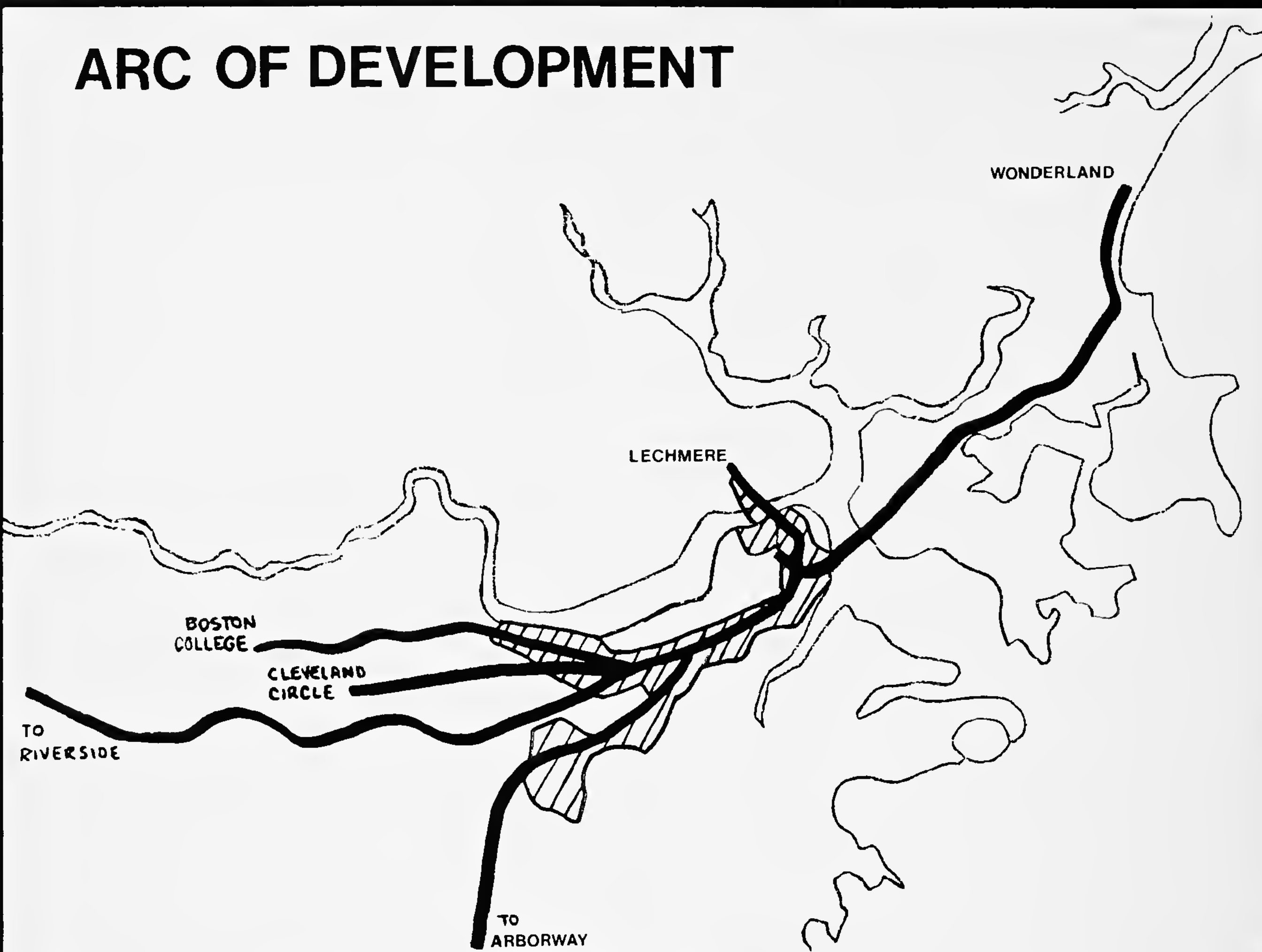
carry 169,000 corridor-to-downtown patrons per weekday. Employment in the Central Business District is rising rapidly. It is feasible to predict that Boston Proper may hold 296,000 jobs by 1975. (This is the number that was previously predicted for the year 1990.) If the transit network were in place as described above with this downtown employment level, and 1975 residential corridor populations are used in the forecasting process, then the Authority is projected to carry about 203,000 downtown tripmakers per day. Further, this figure is expected to rise to about 230,000 by 1990 when 1990 corridor population levels are used.

Much of the boundary of Boston Proper is the Charles River and Boston Harbor. The western boundary is Massachusetts Avenue, a major thoroughfare which is somewhat more of a focus of activity than a divider of activity. In seeking a definition of the Central Business District, Massachusetts Avenue is an extremely good division point. However, those functions which require regional transportation services and many of the activities which seek access to the downtown area are distributed in a pattern which is not divided by Massachusetts Avenue. In fact, many of the activities which are downtown related, particularly educational and medical facilities, are concentrated west of Massachusetts Avenue in a pattern which is an extension of the Central Business District portion of downtown. This growth pattern has been encouraged by the natural growth in downtown Boston and by such factors as available public transportation, prestige Back Bay locations, and expansion of the medical and educational institutions.

The concept sketch, Figure 7-2, shows a great arc of development stretching down from the Government office area of the north, through the retail core and financial districts, following the periphery of the Common, bending to the west, following the Boylston Street corridor to the Prudential development. It is this area that is the financial capital of the New England economy, the most important job concentration of the region. Extending out from this elongated office core along two important avenues are major facilities of the region's second major growth industry--the medical-educational institutions of the greater Fenway-Back Bay area.

> "Medical services, legal services, private education, and government will account for approximately 70% of the new demand for professional-technical skills."*

*Source: MAPC Economic Base, Volume III.



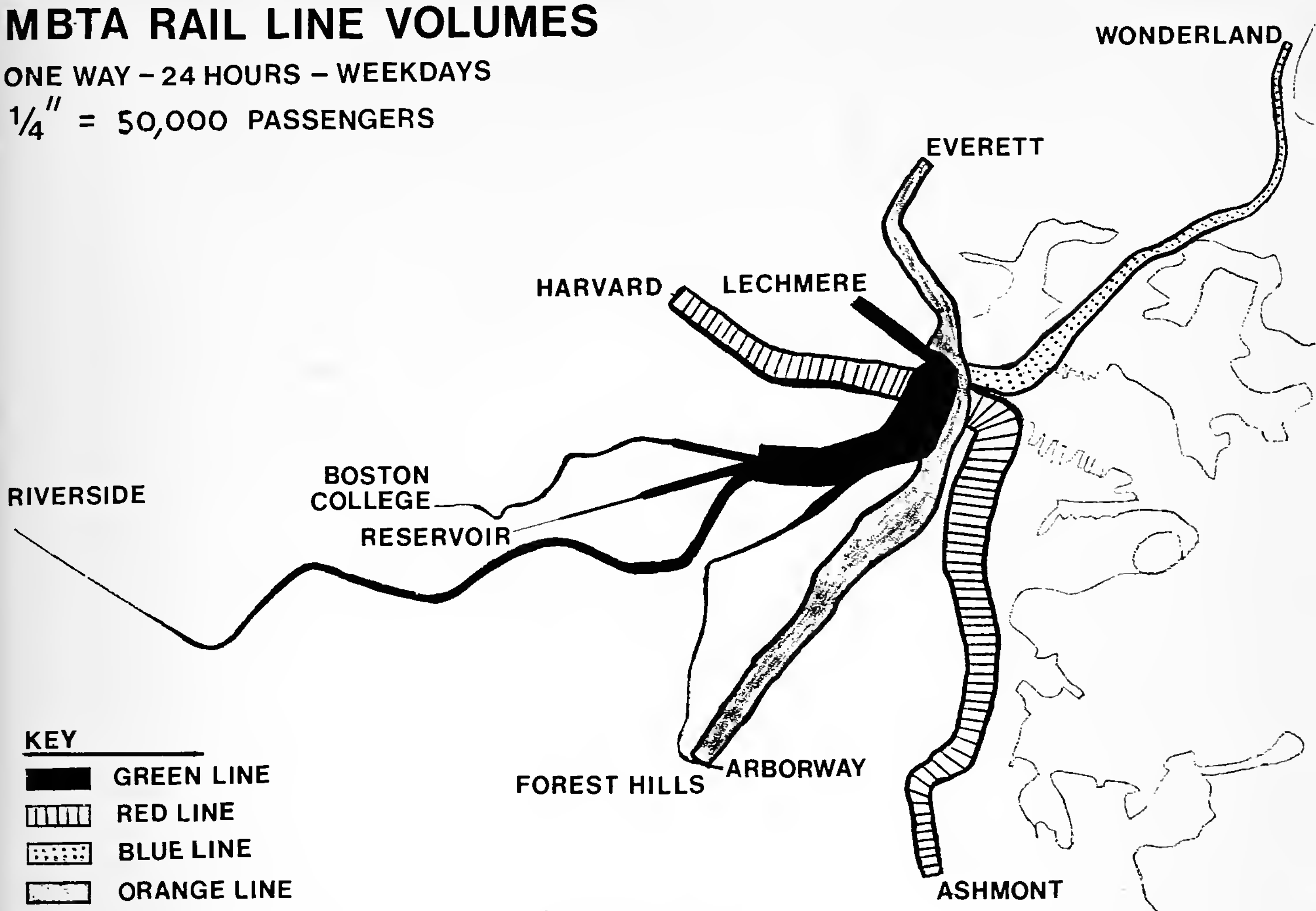
(FIGURE 7-2)

Traffic distribution within the extended district of downtown follows generally the developmental trends which have been outlined. Public transportation in particular has reflected these trends. Figure 7-3 indicates the related traffic volume on the four major rapid transit lines which enter and serve downtown Boston. It can readily be seen from this map that the Green Lines serve a considerable larger volume than any of the other rapid transit lines in Boston Proper. This is due to downtown distribution service which the Green Line provides to all of the other rapid transit lines. The base data show that without the Green Line the Massachusetts Bay Transportation Authority's efficient, long-distance, high-platform rapid transit network would not function properly, as discussed below.

MBTA RAIL LINE VOLUMES

ONE WAY – 24 HOURS – WEEKDAYS

1/4" = 50,000 PASSENGERS



(FIGURE 7-3)

Fifty-eight thousand patrons are collected by the various Green Line segments during the day. Of these, 39,000 are carried into Boston Proper from Kenmore, 10,000 from Huntington Avenue Line, and 9,000 from Lechmere in East Cambridge. Fifteen thousand of the riders have one end of their trip in the Green Line service area and the other end outside Boston Proper, but not necessarily outside areas related to downtown. This means that 43,000 riders alight in Boston Proper daily from Green Line service areas. The Green Line's exceptional ability to distribute riders throughout this area is amply illustrated by the fact that only seven percent (or 3,000) of the Boston Proper patrons alight or board at stations not on the Green Line. The largest of these stations is South Station, which serves about four percent of the patrons who board the Green Line in its service area.

An examination of the role of the Green Line in distributing patrons to and from other corridors is particularly illuminating.

Specifically, about 16,000 riders in the Red Line Dorchester corridor transfer to and from the Green Line at Park Street daily. By far the majority of these patrons travel to or from Back Bay destinations. Some riders transferring from or to the Red Line were actually Orange Line riders making a double transfer--as many as 3,000 of them.

The Blue Line from East Boston provides 6,000 patrons each day with connections or distribution via the Green Line. Ten thousand transfer to and from the Red Line Cambridge subway at Park Street each day, and 3,000 to and from the Orange Line at Haymarket Square. This makes a total of 35,000 patrons making daily transfers to or from the Green Line and using other Massachusetts Bay Transportation Authority rapid transit services as part of the trip. Of these at least 20,000 are alighting at Green Line stations within Boston Proper, with the remaining 15,000 either coming from or going to Green Line stations outside Boston Proper. Many are actually going to the Back Bay or Fenway areas, which are growing most rapidly in institutional functions and which have effectively extended downtown geographically to the west. In Boston Proper alone, the Green Line can safely be said to accommodate 63,000 corridor riders--43,000 from its "own" corridors, and 20,000 from other rapid transit corridors.

In addition to the downtown distribution of its own corridor patrons, and 20,000 rapid transit patrons, the Green Line plays a most important role in intra-downtown trip making. The CASS traffic consultant isolated about 24,000 of these trips, attributable to various phenomena. A large proportion of these trips can be directly attributed to certain access needs in the downtown network. Commuter rail riders, for example, arrive downtown in somewhat remote locations, from a pedestrian point-of-view. Research efforts of the Authority have shown that North Station train riders who finish their trip by transit, use the Green Line in two out of three instances for downtown distribution. Trips between the retail core and Back Bay are largely made through boardings at Green Line stations. Furthermore, the high line volumes on the streetcar-subway are comprised of two-directional distribution. The boarding counts and levels of station activity in the Back Bay area might lead one to the conclusion that the desire lines of Green Line corridor patrons are strongly oriented towards the Back Bay. In fact, at least 60% of the alignments at Copley Square, for example, come from the east, with the Central Subway acting as a shuttle distribution line from other rapid transit lines. Likewise, of the of the 5,800 boardings at Kenmore Square, in the center of the

institutional district adjacent to the west edge of Boston Proper, 4,000 riders were going toward the retail core, not towards the contiguous communities of the west.

The opposite relationship, seems to be true of those alighting at Park and Government Center. These are overwhelmingly patrons from the west who finish on foot the trips made deep into destinations of the Financial District. These destinations are approached from Park Street Station which is approximately a seven-minute walk.

The Green Line serves a variety of functions in downtown and adjacent areas. Not only does it reach the office-oriented land of Government Center and the financial district, it also serves the retail core of downtown, the Boylston Street corridor of insurance-oriented employment, the Prudential Center, the extensions of downtown toward Kenmore Square-Boston University, and the entire Fenway area of education and medical facilities. The linear path of this high density development is an urban form which is most susceptible to the services of a fixed rail rapid transit technology. The congruence of the Green Line services and the growth pattern of downtown has made possible an exceptionally high level of public transportation access within the constraints of existing technology.

The analysis of the role of public transportation in serving this kind of urban land, then, sees two functions being performed in support of the economy. The first, and the best understood, is the bringing together of an extensive labor supply from which firms can choose a high quality, reliable work force. The connecting of the core with the residential hinterland has been the primary design goal of regional transportation systems that focus on a core area. But the effecient assembly of a high quality labor supply does not fully define the role of transit in support of Central Business District location patterns. Many firms in the region have found that by paying considerably higher wages, and providing considerable amounts of free parking they can bypass downtown rents and locate in the hinterlands. Yet, many firms remain in the Central Business District.

The second role, building on the first, is provided by downtown movement systems in general, not just public transportation, as the pedestrian himself is the primary movement system in the inter-connection of spaces. The physical form of Boston renders possible one "spinal" transportation service which links all these

sub-zones, giving equal accessibility to all, and more important, minimizing the time-distance between them.

In the future projections made by the traffic consultant, the role of the Green Line as a critical distribution service for the regional network remains clear. For example, in 1964, 28% of the riders coming in from Charles Station (line volume) transfer for connections to the west on the Green Line. When the new Orange Line alignment is in place, this percentage drops to 24%. The construction of a parallel facility will have diverted only 4% of line volume patrons to change routes. The same relationship applies to transfers from the south on the Red Line; the percentage using the Green Line drops several points to about 25%, with the Orange Line gaining about four points to about 12% of incoming line volume. In summary, analysis of projections shows that the creation of a second line that follows the form of the core serves to relieve the Green Line of some of its distribution functions, but the Green Line remains clearly the most important downtown distributor.

This finding is reinforced by the fact that, following construction of the major rapid transit improvements, downtown Boston will be served by a total of nineteen prepayment transit stations, eleven of which are located on the Green Line. If the extended downtown is used as a basis for discussion, the Green Line provides, in addition to its eleven prepayment stations, twelve surface stations in the reservations of the boulevards it follows. The total of twenty-three Green Line stations in the extended downtown area gives an element of scale to the degree of downtown distribution service offered by the Green Line.

RIDERSHIP CHARACTERISTICS

Public transportation as noted in the beginning of this chapter is no longer the primary mode of the metropolitan region. However, it is clear that public transportation plays an important role in the Inner Cities. The 1963 origin and destination transportation study of the Eastern Massachusetts Regional Planning Project in 1963 recorded 293,478 person trips generated by residents of the Inner Cities area during the morning peak period (between 7:00 A.M. and 10:00 A.M.). Similar data for the entire region showed a total of 1,234,549 peak period trips. Thus, roughly one out of every four peak period trips in the region were generated within the Inner Cities. Of the 293,478 person trips originating in the Inner Cities, 100,447 trips were by

some form of public or mass transportation, and 193,031 trips were by private vehicle. This proportion produces a peak period transit ratio of approximately one transit trip for every three trips made. For the entire Eastern Massachusetts region, the 1,234,549 originating person trips were characterized as 239,150 public transit trips and 995,399 vehicle trips. The regional modal split was thus roughly one transit trip for every five trips made. If the Inner Cities were subtracted from the entire region's total, the modal split for the remainder of the region would have been one transit trip out of every seven trips generated by all modes under analysis.

These simple calculations demonstrate the greater relative importance of public transportation within the Inner Cities as compared to the rest of the region. Another way of assessing the significance of mass transportation in the Inner Cities is by calculating the percent of total regional public transportation travel which originates there. Of the 239,150 originating peak hour trips via public transportation in the Eastern Massachusetts region, 100,447 or approximately 42% were generated within the Inner Cities.

Analysis of destination data for the same period strongly reinforces the prior conclusion on the importance of the Inner Cities as a public transportation market. During the peak hour period, the Inner Cities received 443,818 person trips. Given the regional trip total of 1,243,549 trips, then about 35% of all trips were bound for the Inner Cities. Of these trips, 174,744 or 37% were by mass transit in some form. Thus, 63% of trips into the Inner Cities from the suburbs were by auto.

Table 7-1 presents a detailed breakdown of the 293,555 trips by all modes that originated in the Inner Cities. It shows for each of twenty-two superzones the number of trips from these zones to the same zone, to Boston Proper, to a combined Back Bay-Fenway zone, to the remainder of the Inner Cities, and finally to outside the Inner Cities Area. The table also shows the percent of trips via public transportation to any one of the above areas from each of twenty-two superzones.

Several important aspects of transportation behavior within the area are shown or can be derived from the table. On a regional basis about 11% of all A.M. peak period trips had Boston Proper (CBD) as their destination. Within the Inner Cities, 51,228 trips or slightly over 17% were destined for Boston Proper. In terms of relative reliance on transit for downtown trips, 71% from the Inner Cities, compared to 64% from the entire region were by this mode. Therefore, the Inner Cities generated relatively more trips to Boston Proper and more trips by transit to Boston Proper than the rest of the region.

Table 7-1

Total A.M. Peak Hour Trips from Study Area Superzones to Selected Superzones and Outside the Study Area by All Modes and the Percent of the Trips to the Superzones that were by Public Transportation

Area Superzones	Internal	%	Downtown	%	Back Bay Fenway	%	Remainder of Study Area	%	Outside of Study Area	%
E. Boston	3,450	43.3	3,897	86.2	1,149	65.1	3,743	33.5	5,880	14.8
Charlestown	1,111	22.9	2,268	83.2	476	46.0	9,594	9.8	1,595	24.0
Downtown	1,818	43.6	1,818	43.0	829	59.3	1,770	31.9	3,478	25.1
No. End	0	-	1,180	58.4	557	57.8	871	30.7	893	41.2
West End	51	-	370	24.8	839	41.5	1,293	48.4	811	45.2
Back Bay	348	78.1	1,314	56.0	944	65.4	2,431	19.5	865	36.8
So. End	841	25.9	1,918	68.3	837	74.0	1,460	63.2	2,529	54.3
Jamaica Plain	1,796	28.7	1,937	86.0	1,274	60.3	2,369	40.6	3,544	23.5
Fenway	1,306	20.3	2,825	86.8	1,769	26.8	2,464	44.2	1,636	39.3
Allston	784	20.7	2,117	77.7	1,428	58.1	3,595	31.8	1,822	32.4
Brighton	1,895	5.8	3,113	70.3	1,131	45.1	5,677	37.2	2,298	22.1
No. Brookline	3,037	8.0	4,775	66.0	2,866	30.7	4,098	19.0	2,179	8.1
So. Brookline	2,126	11.4	1,859	56.3	719	16.6	3,296	17.6	1,736	9.5
Newton	15,312	11.5	3,897	52.9	1,601	23.0	4,018	11.8	11,124	5.0
Watertown	3,984	10.3	1,220	74.0	890	21.9	5,279	25.5	3,608	10.5
E. Cambridge	2,281	25.8	1,810	77.8	1,000	40.1	6,514	38.0	2,355	17.3
W. Cambridge	7,809	34.1	2,514	84.2	1,176	38.6	5,639	34.6	3,313	20.1
Somerville	6,684	33.1	4,421	71.0	947	57.5	9,410	40.2	5,569	25.5
Everett	4,543	26.0	2,583	64.3	312	44.5	3,463	35.9	3,471	14.6
Chelsea	4,257	35.1	1,219	79.4	492	24.7	2,941	35.5	2,092	19.5
Revere	3,366	26.1	2,730	73.4	508	23.6	3,734	25.8	2,798	10.7
Winthrop	1,749	33.1	1,443	81.0	194	40.2	2,357	23.0	1,129	3.3
TOTALS	68,548	24.2	51,228	71.1	21,938	42.7	86,016	29.7	64,725	18.8
GRAND TOTAL	293,555									

SOURCE: EMRPP - 1963

Table 7-

The table shows that there is considerable variation among the superzones for Boston Proper trips via public transit. The Blue Line communities, East Boston, Winthrop, Revere and Chelsea, show a greater usage of transit for their trips to Boston Proper than the Inner Cities average of 71%. In the Green Line service area, the data shows more variable transit behavior with some areas such as Allston, Brighton and North Brookline being above or near the Inner Cities average, while other areas such as South Brookline and Newton display percentages well below the average.

For trips originating in the Inner Cities, approximately 33% were by public transportation, while for trips destined for the Inner Cities 37% were by public transportation. Thus, it can be seen that although the Inner Cities area is important as an originator of trips, it assumes more importance in total regional trip behavior as a receiver of trips. Obviously, the Inner Cities area assumes greater significance as a receiver of trips because it contains the Boston Proper superzone. This 1,025 acre area received 144,122 trips or about 11% of the total A.M. peak hour trips from Eastern Massachusetts. Of the 144,122 trips into Boston Proper, 91,751 or nearly 64% were via public transit. This means further that of all the Region's transit trips in the A.M. peak period, 34% were destined for Boston Proper alone. Of the 100,447 transit rides generated in the Inner Cities (shown on Table 7-2), 47% were bound for the expanded definition of downtown Boston. Earlier it was noted that about 34% of regional transit trips were downtown oriented. Thus, the Inner Cities transit riders were more oriented to Boston Proper than transit riders in the entire region. However, there were some interesting variations about the Inner Cities area. Transit riders in the Green and Blue Lines areas in general had a higher than average propensity to be oriented to Boston Proper. North and South Brookline, Fenway, Newton and Brighton in the Green Line area had high or above average transit ridership figures for Boston Proper. A similar characteristic was true for Revere, Winthrop and East Boston. For the other superzones of the Inner Cities, the Boston Proper transit market was generally below average. Charlestown was an obvious exception.

Cities such as Somerville and Chelsea were not, in relative terms, oriented to Boston Proper. The former area sent only 33.2% of its total transit riders to the expanded downtown, the latter community only 26.9%. Both of these cities of course lack direct rapid transit access to the core. These figures contrast sharply with North Brookline in the Green Line area where 87.9% of all transit riders were destined for the expanded downtown Boston.

Table 7-2

A.M. Peak Hour Trips by Public Transportation from Study Area Superzones to Selected Superzones and to Outside the Study Area and the Percent Distribution of these Trips

Study Area Superzones	Internal	%	Downtown	%	Back Bay Fenway	%	Remainder of Study Area	%	Outside of Study Area	%
E. Boston	1,507	19.4	3,362	43.4	749	9.7	1,256	16.1	876	11.4
Charlestown	255	6.9	1,888	51.1	219	5.4	942	25.5	384	10.5
Downtown	782	22.4	782	22.4	492	14.1	566	16.2	873	25.0
No. End	0	-	690	41.9	322	19.5	268	16.2	368	22.4
West End	0	-	92	6.4	349	24.3	626	43.6	367	25.6
Back Bay	272	11.2	737	30.4	618	25.5	476	19.6	319	13.2
So. End	211	4.8	1,311	29.5	620	14.0	923	20.8	1,374	31.0
Jamaica Plain	516	10.9	1,667	35.1	769	16.2	962	20.3	833	17.6
Fenway	266	5.4	2,453	49.8	475	9.6	1,091	22.1	643	13.1
Allston	163	3.7	1,645	37.6	830	19.0	1,144	26.2	591	13.6
Brighton	111	2.0	2,190	40.1	533	9.7	2,114	38.7	508	9.4
No. Brookline	536	9.7	3,153	57.0	880	15.9	780	14.1	177	3.3
So. Brookline	243	11.3	1,048	48.5	120	5.6	582	27.0	166	7.7
Newton	1,828	34.5	2,064	38.9	369	7.0	476	9.0	564	10.7
Watertown	413	12.7	904	27.9	195	6.0	1,351	41.7	379	11.7
E. Cambridge	589	11.2	1,401	26.6	401	7.6	2,477	47.0	408	7.8
W. Cambridge	2,667	33.9	2,118	26.9	454	5.8	1,953	24.8	668	8.5
Somerville	2,218	20.0	3,143	28.3	545	4.9	3,785	34.1	1,424	12.9
Everett	1,184	25.0	1,661	35.1	139	2.9	1,244	26.3	508	10.8
Chelsea	1,497	37.0	968	23.9	122	3.0	1,046	25.9	409	10.2
Revere	1,011	23.0	2,005	45.6	120	2.7	964	21.9	300	6.9
Winthrop	580	24.2	1,170	48.8	78	3.2	544	22.7	38	1.6
TOTALS	16,849	18.7	36,452	36.3	9,399	9.4	25,570	25.4	12,177	12.1
GRAND TOTAL	100,447									

SOURCE: EMRPP - 1963

Table 7-2

In terms of travel to the Back Bay-Fenway combined zones, 9.4% of all A.M. peak public transit trips flowed into this zone. However, for the Blue Line communities this area was not, relatively speaking, a prime zone for its transit riders. Relatively few of the transit riders from Revere, Winthrop and Chelsea were headed for the zone. East Boston was an exception with nearly 10% of its transit patronage headed for the Back Bay-Fenway. In the more proximate Green Line areas, there was a greater attraction for the Back Bay area with North Brookline, Allston, and Brighton having higher than average rates of transit travel. Allston, for example, sent 19% of its peak transit riders into the Back Bay-Fenway zone--more than twice as large a percent as the Inner Cities average. Other Green Line communities such as Newton, South Brookline and Watertown were below the average, but they were not as far below as many of the Blue Line communities. Small areas of the City of Boston such as the West and North Ends, the retail and financial district and the Back Bay itself had above average transit travel to this zone.

Tables 7-3, 7-4, and 7-5 show the superzones in order of ranking as to the percentage of A.M. peak period trips by all modes to an Extended Downtown, the number of transit trips to downtown, and the modal split to downtown, respectively.

It must be cautioned that the relative distribution of transit trips of a given zone to certain other zones does not tell the whole story as to whether or not the given zone is a good market for transit trips. What is also of significance is the absolute number of trips generated in the zone. Reference to Table 7-4 shows that the greatest number of transit trips in the study area came from the Somerville, East Boston, and North Brookline zones in that order.

These tables show that in communities such as East Boston and Somerville the more important reason for their high totals is their larger propensity to use transit and not the volume of potential trips to Boston Proper. For North Brookline the opposite conclusion is suggested, i.e., the high transit total was brought about by the fact that so many trips were destined for Boston Proper, and not because of exceptionally high transit patronage rates. The inclusion of the Newton and Winthrop communities in the table enables one to see the workings of both factors in determining their actual transit flow to Boston Proper. Newton generates as many trips by all modes to the area as does East Boston (i.e., 3,879 trips) but because of the former's much lower transit use rate, its actual number of transit trips is much lower. Winthrop on the other hand has almost as high a transit use rate as East Boston, but it does not have a large volume of total trips bound for Boston Proper, with the result that its actual volume of Boston Proper public transit trip is considerably lower than East Boston's.

EXTENDED DOWNTOWN TRIPS BY SUPERZONE

Superzones ranked by percentage of A.M. peak-period trips by all modes to Extended Downtown, including Back Bay and Fenway superzones; absolute number of trips and percent by transit.

ORIGIN	% TO DOWNTOWN	NUMBER OF TRIPS TO "DOWNTOWN" BY ALL MODES	% BY TRANSIT
North Brookline	45.1	7,641	52.8
Allston	36.4	3,545	69.8
Brighton	30.3	4,294	63.4
Jamaica Plain	29.4	3,211	75.6
East Boston	27.8	5,046	81.5
South Brookline	26.5	2,578	45.3
Winthrop	23.8	1,627	76.2
Revere	23.7	3,238	65.6
Everett	20.1	2,895	62.7
East Cambridge	20.1	2,810	64.1
Somerville	19.9	5,368	68.7
Charlestown	18.2	2,744	76.8
West Cambridge	18.0	3,680	69.7
Chelsea	15.6	1,711	63.7
Newton	15.1	5,498	44.3
Watertown	14.1	2,210	52.1

NUMBER OF TRANSIT TRIPS TO DOWNTOWN
(ZONES 012-053, 114-117)
24 HOURS

RANKED FROM HIGHEST TO LOWEST

Somerville	4,688
East Boston	4,111
North Brookline	4,033
Brighton	2,723
West Cambridge	2,570
Allston	2,475
Chelsea	2,465
Jamaica Plain	2,436
Newton	2,333
Revere	2,125
Charlestown	2,107
Winthrop	1,848
East Cambridge	1,802
Everett	1,800
South Brookline	1,168
Watertown	1,099

MODAL SPLIT TO DOWNTOWN (INCLUDES BU-KENMORE, BACK BAY-FENWAY)

(PERCENT BY TRANSIT)

RANKED FROM HIGHEST TO LOWEST

East Boston	81.5
Charlestown	76.8
Winthrop	76.2
Jamaica Plain	75.6
Allston	69.8
West Cambridge	69.7
Somerville	68.7
Revere	65.6
East Cambridge	64.1
Chelsea	63.7
Brighton	63.4
Everett	62.7
North Brookline	52.8
Watertown	52.1
South Brookline	45.3
Newton	44.3

The Green Line has demonstrated a remarkable stability of ridership when compared to other services over a fifteen-year period. Between 1956 and 1967, one-way boardings for all rapid transit lines in the system declined by a factor of 27%. The most stable of the lines over time is the Green Line which lost only 16% of its riders. Much of this stability can be attributed to the addition of the Riverside Line; however, even if the added ridership of this line is subtracted, the Green Line still records the best performance with only about 22% loss. At the opposite end, the Orange Line suffered the most over the time period, with a decline of 45% in patronage. Finally, the Red and Blue Lines acted like the system as a whole, with a 26% loss for the Red Line and 25% for the Blue Line.

Within this time frame, the middle of the last decade was a distinct turning point for the transit system. The system as a whole hit its lowest point of this period in 1964, registering absolute gains through 1967. There are important variations, however, in the timing of this turn-around. Specifically, the Green Line started its increase in absolute volumes after 1962, two years before the system as a whole, with an absolute increase of 14,000 by 1967. On the other hand, the Orange Line dropped about 7,000 passengers during the same period without scoring an annual increase. The Red Line made its turn-around in 1965 with about 9,000 increase overall. The Blue Line finally did increase by 1966, but its variation over the 1963 through 1967 period was less than 1,000.

There were no variations in the pricing system while the above increases were taking place. However, in December of 1968 bus fares were doubled and transit fares went to 25 cents. The 1968 data was taken that same week and may be reacting somewhat to the fare hike. The same pattern however emerges as before. The Orange Line was the hardest hit, dropping 11% in one year. The Blue Line and the Cambridge portion of the Red Line suffered a 6% drop, while the line up from Dorchester showed a surprisingly small 3% drop.

The Green Line, which had been increasing steadily since 1963, showed very little effect of the fare increase, with a statistically insignificant 1% drop in ridership. Its component parts reveal differing histories of ridership. For example, since the fare hike of 1961, the Huntington Avenue Line has recorded an increase for every year, including the year of the 1968 fare hike, based upon a one-day annual count. In this time it has risen from 11,000 in 1961 to 15,000 in 1968. A similar overall record has been made by the Riverside Line which has increased almost every year with a similar rise from 11,000 to 15,000 since 1961.

The one-day annual count data for the Beacon, Commonwealth and Watertown Lines reveals a pattern of interest to this study. The data for these lines for the years 1961 and 1962 reveals sharp fluctuations. During this period, the lines coming in on Commonwealth Avenue suffered an 18% loss in one year, while Beacon Street patronage fell by an amazing 30%. Since that time, the Commonwealth Avenue Line has picked up patronage levels again, but neither Beacon nor Watertown Lines were ever to fully recover lost riders. Analysis of the Commonwealth Line was complicated by the adoption of a parallel bus for local riders.

The sharp drop between 1961 and 1962 was undoubtedly due at least in part to a series of sharp reductions in service which were put into effect during that period as economy measures. It may have also been influenced by the 1961 fare increase which went into effect a month before the 1961 count was taken.

Comparing the performance of the Green and Orange Lines supports the concept that the Green Line labor force is based on a segment of the region's economy which is growing in the transit-served areas of downtown (largely the extended downtown) while the rapid transit lines tend to serve a population whose employment patterns are becoming somewhat less oriented to downtown or more automobile-oriented for downtown trips. The Orange Line by contrast goes through relatively low income areas, both to the north and to the south of the core, and is not well equipped to capture park-and-ride patrons from areas beyond its service. The moderate performance of the Red Line can be attributed to the existence of a full cross section of workers in Cambridge, with the non-blue collar workers comprising a stable element of ridership. Likewise, the Blue Line data shows that recent increases in this line are directly attributable to the use of parking facilities at the northern end of the line. For example, Maverick Station lost ridership sharply in 1968, while all the outlying stations showed increases.

These figures represent relative declines, often reflecting the behavior of communities with previously high reliance on public transportation. Further, the pattern over time obscures the facts revealed by the absolute numbers involved. Thus, any system of priorities that does not provide for the needs of close-in lower income communities is questionable. The small area of East Boston sends as many trips by all modes and many more trips by transit to downtown than does the large area of Newton; similarly, the working class community of Somerville, which has no rail connection to downtown, sends more transit trips to downtown than North Brookline which has three direct rail lines (Table 7-4).

In the following pages, an attempt is made to review socio-economic variables and present a simplified summary analysis of their interaction. Three factors have been isolated: 1) the principal riders of our facilities, 2) the relation between our facilities and their housing choices, and 3) given their location, their propensity to choose our services. From these elements, it is feasible to attempt to predict the effect of a service improvement on a community.

Our concern throughout this socio-economic study has been the sub-dominant residential life style, the location patterns of a minority of regional residents, those who live in the Inner Cities area. Transit services, at one time the staple of the majority, have become more and more relevant to the needs of particular groupings of people. The determinant factors include: stage in the life cycle, with particular respect to the child rearing process of families; density patterns at place of occupation (including students), and need for a second member of the household to join the labor force.

Table 7-6 presents in brief tabular form a summary of variables that highlight the unique character of each of the lines. The streetcar routes and the Blue Line rapid transit are presented individually. What is to be learned from these tables that is of real significance and cannot be overemphasized is the degree to which the streetcar service is interwoven into the daily life style of the service area.

The Commonwealth-Beacon Line serves an older age group than the Huntington Line. Blue collar workers are more predominant on the Watertown Line. There are fewer office clerks riding the Huntington percentagewise than any other line. There is more intra-line inbound riding on the Riverside Line that alights before Kenmore than on any other line. There is a lower income group and a higher incidence of transfers or changes of mode on the Blue Line as compared to all other lines.

These findings, and many more which can be derived from the chart, detail on a simplified level those socio-economic characteristics to which a public transportation operation must respond. This chart demonstrates the importance of investigating and responding to the individual makeup of each of the component lines in the Inner Cities, especially the streetcar lines, before implementing both staged and comprehensive improvements.

	INDIVIDUAL LINES					
	Green Line	River-side	Hunting-ton	Watertown	Commonwealth -Beacon	Blue Line
Without Autos	39%	22%	44%	38%	45%	35%
Females	52%	47%	51%	52%	54%	48%
Driver's License	54%	65%	45%*	48%	57%	49%
			*13% are underage.			
Median Income	$9,000	$13,050	$7,290	$7,800	$9,600	$6,917
Median Age	32	32	23	39	44	42
Persons in Households	3.41	3.92	3.19	3.75	2.79	NA
Trips:						
Work	47%	50%	32%	51%	50%	60%
School	21%	14%	36%	13%	16%	7%
Other	32%	36%	32%	36%	34%	31%
Professionals	15%	23%	9%	12%	18%	8%
Office Clerks	24%	21%	16%	23%	28%	31%
Blue Collar	14%	11%	9%	26%	8%	28%
Sales & Service	6%	6%	7%	3%	6%	1%
Students	26%	26%	46%	16%	21%	13%
Inbound Alightments before Kenmore or Symphony		.22	.18	.15	.14	NA
Trips making trans-fers or change of mode.	25%	26%	22%	22%	16%	40%

Observation of the housing patterns of the Green Line area reveals how the presence of transit services affect the use of the housing stock. While transit may not influence the form taken by the majority of new single home developments, its effect on the existing housing near its services is market. Housing located near Green Line facilities has a significant concentration of groups other than families in the child rearing stage of their lives (25 to 40 years old). The family size of Beacon and Commonwealth patrons is significantly smaller than other lines in the system; in fact, the percentage of unrelated individuals in households is among the highest and is quite comparable with university areas of Cambridge, indicating the presence of both youthful and elderly persons.

The desires of families with children to seek housing patterns with more space and often better schools gives the Green Line service area as a whole an underrepresentation of employed persons ages 25 to 40. When the Green Line service areas, such as Newton and South Brookline, are excluded, the streetcar-oriented communities of Allston, Brighton, North Brookline, Back Bay and Fenway would show even more marked differentiation by age. For the Green Line service area, those 16 through 25 comprise 23% of the trip making population for all modes, while those 26 through 35 comprise only 17% of the trip making population. The effect of age on trolley ridership is markedly increased by the differing tendencies of these groups, once located, to consume our services: those 16-25 make up 31% of all trolley riders, with those 26-35 comprise only 12%.

It also appears that streetcar tripmakers between the ages of 25 and 40 are significantly less affluent than both younger and older tripmakers. The data show that those residents at this stage in the life cycle are less likely to be so located by preference as their residential options are more constrained by income. This phenomenon is similarly revealed by the fact that the slowest public transportation services, the city bus, are predominantly patronized by low income users, those with the fewest options to locate well in respect to high-speed services, or to choose private transportation instead.

The riders who have the greatest impact in a particular community are those individuals who choose public transportation services, and make locational decisions with this factor in mind.

Females in the labor force appear to have a stronger propensity to use transit services, and this propensity is less affected

by external variables such as income level than is the case for male workers. For example, a woman coming from a family making over $10,000 has the same tendency to choose transit for trips that end in a railed vehicle as does a femaleworker from a family of $4,000 annual income. Thirty-two percent of all work trips made by women from neighborhoods served by transit have a railed vehicle as part of their trip. For males the figure is consistently lower, and more subject to variation by income level.

It is significant that females in the labor force seem to be positively correlated with both incidence of "Blue Collar" and "Unrelated Individuals." These two elements of the market for female riders have two distinct levels of constraint placed on their housing options. The females living in apartment situations have, by and large, considerably more ability to locate near public transportation services if they so choose. If public transportation is relevant to their lives (largely determined by the density patterns at their work place), they can quite easily locate to facilitate their trip to work. By our definition, it is this group that has the options.

By contrast, the lower (or lower middle) income working family has many locational criteria that take precedence over the proximity of good transit service, especially to the female's job. Families take more space than "roommate" arrangements, and much of the desirable space surrounding transit facilities (such as the important Commonwealth Avenue service through Allston-Brighton) is taken up by dense apartment living arrangements. The presence of a strongly functioning transit line decreases the ease of finding a home big enough for a family within the constraint of the low income budget.

In short, housing arrangements catering to the needs of small families and unrelated individuals can effectively outbid working class family housing. There emerges on a line of high service levels, such as the Commonwealth Line, a pattern in which young and other unrelated households appear in disproportionate numbers among the ridership. Thus, while secretaries and office clerks (largely female) comprise only 14% of the region's total labor force, they appear as 28% of the Commonwealth ridership. Of course, these categories are not neat and mutually exclusive, for hidden within working class residential areas are households of unrelated individuals, too poor to purchase more accessible locations. Likewise, in areas of dense apartment settlements, there are those families who are willing to pay the higher rent for the space they choose to have.

By observing the differing living arrangements of our female ridership, we have been able to speculate on the existence of conflict between two sectors of the housing market competing for space close to the downtown employment, both elements desiring the kind of older housing stock available in Inner Cities neighborhoods.

These conclusions emphasize the vast scale of the housing stock already organized around our services. In no subregion is this pattern more physically evident than along Green Line median strip facilities. Investments in the Green Line are needed to strengthen this pattern.

Much of the ridership data for the Green Line reveals an interesting reflection of the makeup of its component communities. It was in 1963 that the pattern of ridership decline was reversed; this point in time seems to represent a transition between two residential phenomena. The pattern of decline in reliance on transit for trips in general was overtaken by an increase of reliance on transit for a specific group of trips. This pattern directly reflects the transition in job categories in the downtown area. At about this time the rise in office and institutional jobs overcame the decline in jobs with less need for location in the high density core.

The early turn-around in the ridership of the Green Line also reflects other forces of demographic change affecting the Green Line communities. With a general rise in affluence has come a significant rise in the purchasing power of young adults. This, coupled with the findings of MAPC population studies which indicate that marriages come later in life for individuals in this metropolitan region than in any other section of the country, has substantially increased the demand for densely settled, older units of housing. This pattern would be serious if the only consideration were the purchasing power of young adult workers living in housing units independent of their families; or of young married couples with both members in the labor force but without the need to locate in an environment conducive to child rearing. However, the particular problem of the Boston region is compounded by the considerable influx of students. The needs of this group are quite similar to the young married group, except that they have more constrained location requirements near universities. Because of this similarity of housing needs, the students and university-related residents cause a rapid dynamic growth in the young adult apartment-seeking population as a whole. Coupled with a working population (the majority of whom are female) which wants to locate near nodes of activity created by the presence of other elements of their age group causes somewhat of a stampede effect for such areas.

For the purposes of transit data analysis, the presence of students may be of interest predominantly because of its effect on the housing market. Major exceptions to this observation are the growing number of non-resident schools which rely on a commuting pattern. The Governor's Task Force on Transit for Columbia Point, for example, forecasts a daily transit usage of more than 10,000 trips to University of Massachusetts, Boston alone. Even in resident universities there is a significant market for off-peak, non-work trips, a pattern intensified by the growing uses of these campuses for night school extension functions.

This reference to the demographic change taking place in the Green Line area is sufficient to point out the necessity of taking specific action in transportation policy to encourage the settlement and development patterns which are currently in flux. It is clear that, largely because of the quality of service offered, no sector of the region is more influenced by the residential location decisions of households which desire to be near transit facilities and have sufficient income circumstances to carry out these desires. What is not clear, however, is whether transit-oriented (largely downtown employment oriented) household units will continue to outbid other groups for this high-access housing unless there is an obvious and continuing commitment on the part of the Authority to maintain and improve such service. This is the immediate high priority need revealed by the Central Area Systems Study.

Despite the observed need, there is a feeling among the public that the long term retention of streetcar service is by no means assured. The unstated belief that they may go is but a logical outgrowth of repeated personal observations.

The long term uncertainty, based on the lack of commitment, is of most relevance to builders of apartment houses in areas in question. A phenomenon deserving more direct attention is the belief that the Authority has little intention of providing maintenance and high levels of service from day-to-day. Much of the bitterness on this subject can be traced to just cause. In the course of general research on this project, a little-used file of 1963 data was discovered which recorded travelers who had changed modes permanently. Predominant in this data were streetcar users who gave up reliance on the service in the two years (mainly 1962) before the interview. Analysis showed that most of these individuals did not change modes because of change of employment or residential location, but rather because the

quality of service was reported as cut to unacceptable levels. Indeed, it was the publicly stated policy of the MTA, predecessor to this Authority, at the time of the adoption of the Riverside Line that once this facility was established, the Beacon Street trolley service would be dropped completely.

The future success of the Green Line in building ridership will be largely dependent upon its ability to attract transit users to settle near its stations. A case in point is the Riverside Line where the service has deteriorated and fares risen by a factor of 250%, but ridership has nevertheless doggedly increased over time. This suggests a pattern of residential in-migration by those who have decided to use transit for the journey to work. However, as long as the public perceives or imagines a lack of commitment to improve that service, this critical settlement pattern is in jeopardy. The conclusion again points out that there is an existing trend, already underway, that must be supported and encouraged by action lest the beneficial cycle be lost for lack of commitment.

Part of the local concern has arisen because of speculation on the effect of transportation improvements on the stability of the present Inner Cities communities of the inner Green Line. There has been a realization of late that the social changes brought about by public investment have received insufficient attention in the planning process, and that public and institutional investments have the effect of driving population groups away in favor of other invading groups. The pattern we are seeking out is one in which a new group of household seekers, for one reason or another, has the ability to outbid the present population for their housing stock; in this case because of a major change in transit access. The most likely pattern to occur would find residents newly attracted to a community because of its connection to the downtown and transit network, making housing more expensive for others, perhaps resulting in driving them out. In terms of physical plant, this often takes the form of extensive rehabilitation, done by the owner who is aware that good quality housing can now get a better price than before the access change.

In the inner Green Line service area, we can conclude the service improvements will not bring about a radical change in the social characteristics of the community, for this process has already begun and is well advanced.

The "stability vs. invasion" question for the inner Green Line area may be unique for certain parts of the area such as North

Brookline may be going through a form of social transition that might be arrested by dramatically improved service dependability. In reaction to poor transportation quality, such as that demonstrated in 1962, this community seems to be turning away from transit; indeed, it has the income characteristics to indulge in any mode preferred. This community, whose very existence grew out of the streetcar line, has reached income levels where its members can opt away from transit usage at will, as it becomes socially more and more similar to Newton. The process of turning away from a downtown orientation might well be challenged by a new level of linkage, encouraging core-linked households to compete for this transit-rich housing.

In short, the data presented earlier showing the sharp lack of Blue Collar populations around the streetcar lines, the high degree of both females in the labor force, and unrelated individuals living as households, as well as the presence of students, all converges to indicate that the Green Line housing stock, and the makeup of the population that inhabits it, represents an area needing immediate dramatic improvement in transit quality. Without such an improvement, the continuation of the beneficial trends of residential locations supporting growth in ridership is thrown dangerously into jeopardy.

CHAPTER 8

ENGINEERING SOLUTIONS FOR THE CENTRAL AREA

THE PROBLEMS

The most serious problems of the Green Line are the result of the "bottleneck" nature of its operation and the resulting severe restrictions on capacity and regularity.

The Blue Line's worst problems are caused by its lack of adequate downtown distribution, which makes it relatively unattractive to many North Shore commuters and Airport users.

Both lines suffer from antiquated rolling stock, and facilities for operation and maintenance.

Over the years, the influence of public policy has forced a "penny-pinching" philosophy upon the Authority's management, in an effort to hold down the annual operating "deficits." In contrast to the typical profit-motivated private enterprise, the Authority has not seen much of the replacement and upgrading of equipment and facilities which, in private business, is normally financed out of depreciation reserves. Progressive obsolescence and deterioration have been the inevitable result, with operating losses climbing at an accelerated rate. The massive modernization and expansion programs now underway for the Red and Orange Lines will make up for some of the years of neglect. The Blue and Green Lines, however, are not receiving the benefit of such programs, except for the modernization of some stations. Fortunately for the Blue Line, many of its facilities are of more recent vintage than those on the Green Line, and thus have suffered less from the ravages of time. The Green Line today, therefore, has far more than its share of problems.

The effect that these run-down conditions have had on employee morale, pride of accomplishment and pride in the organization is something we cannot measure, but we suspect that it has been substantial.

Really significant improvements in speed, efficiency and capacity cannot be achieved without the expenditure of large amounts of capital. This study focuses on the problems of how that capital should best be used.

In the Authority's application for CASS Technical Studies Grant, dated May 27, 1968, many of the specific problem areas which contribute to the present unhappy conditions were identified. They are discussed in Chapters 6 and 10.

The principal engineering consultant, DeLeuw, Cather & Company, was assigned a specific scope of work which included feasibility and cost estimates of a number of engineering solutions in the more obvious problem areas. Their assignment, however, was not limited to problems in specific areas but was broad enough to permit them to study innovative engineering solutions as they suggested themselves during the course of the study.

DeLeuw, Cather & Company developed a systems approach to the solving of Green Line problems. Three alternative system concepts were developed and these are discussed fully in Chapter 9. The systems were designed to be developed in stages and each one contains the solution to as many of the specific engineering problems as possible. The following discussion of the major engineering problem areas and their possible solutions should give the reader a better insight into the merits of the systems solutions discussed in Chapter 9.

PAST ATTEMPTS AT BREAKING THE "BOTTLENECK"

The "Metropolitan Planning Report"

Many of the proposed engineering solutions of the CASS Study are not new ideas. Some of the concepts were first suggested as far back as 1926.

The Report of the Massachusetts Division of Metropolitan Planning on "Improved Transportation Facilities in the Boston Metropolitan District," issued December 1926, had this to say about congestion in the Central Subway:

> "When the original subways were designed and constructed, it was felt that intown terminals constituted the most logical provision for the convenient handling of this class of traffic and the early plans were predicated largely upon the providing of such terminals for the several radiating lines coming into the city from various directions. Experience has demonstrated the fact that the intown terminal is highly objectionable from the operating standpoint. It tends to concentrate tremendous volumes of traffic at these central points

and renders it difficult to carry the traffic away as rapidly as it accumulates, due largely to the fact that the passengers are destined from a great variety of points and each must await the arrival of a given car, thus greatly congesting the station platforms. This selective service, giving to each passenger the choice of a variety of cars at a given station terminal, has introduced tremendous difficulties in recent years, because of the necessity of berthing the cars at different points along the platform according to the order of their arrival, so that there is a continual longitudinal movement of passengers in conflicting directions along the platforms, producing confusion and excessive delay in loading. This objection applies particularly to those stations where surface cars coming from the various feeder lines are brought into the intown subway stations as in the case of the Boylston and Tremont Street Subways."

In 1926 there was, of course, no Riverside Line and no Huntington Avenue subway, but six independent surface car routes made their intown terminus at Park Street Station; three entering the subway near Kenmore and three entering at the Public Garden. In addition there were five routes entering the Tremont Street subway at the Broadway portal and operating through Park Street Station to the North Station or Lechmere.

Although the eleven routes of 1926 have been reduced to four (not counting the Watertown Line which has been discontinued on an experimental basis), many of the problems described in the 1926 report still exist. Many of the engineering solutions explored in the CASS Project were similar to those recommended in the 1926 report, although construction problems were considerably different due to physical changes in the City during the intervening years.

In the 1926 report, the Division of Metropolitan Planning recommended conversion of the Central Subway to high-level platform operation with a through connection to the East Boston Line (now called the Blue Line). Three alternative alignments for a subway connection between Park Street and the Blue Line were proposed. Two of them would have eliminated the extension to Bowdoin and required a new station at Scollay Square (no Government Center). The third scheme proposed a connection from Bowdoin Station to Park Street Station passing under the State House. Rapid transit trains were to operate from East Boston through the Central Subway to the Kenmore portal. From there they were to pass along the median strip of Commonwealth Avenue to a

terminal near Warren Street in Brighton where transfer was to be made to streetcars. The Watertown streetcar line was to be diverted to this Warren Street terminal. Just how high-level platform cars would be operated successfully along the median strip of Commonwealth Avenue to Warren Street was not made clear in the report.

The Tremont Street subway was to be extended from the existing portal at Broadway to emerge on the New Haven Railroad right-of-way with a stop at Back Bay Station. From there it would have followed the right-of-way of the Boston & Providence (New Haven) Railroad to a point near Massachusetts Avenue. From here the tracks were to cut over to Huntington Avenue somewhere between Massachusetts Avenue and Forsythe Street, and thence under or along Huntington Avenue to a new terminal near Brigham Circle where transfer was to be made to trolley cars. Low-level platform cars were to be operated on this line between Lechmere and Brigham Circle.

With this arrangement, all lines were to pass through Boylston and Park Street Stations. In this four-track section, the two westerly tracks would have carried high-platform service; the two easterly tracks low-platform service.

The report also suggested the extension of service beyond Lechmere to Washington Street in Somerville, or possibly Union Square, or North Cambridge.

The Coolidge Reports

The well-known reports of the Metropolitan Transit Recess Commission of 1945 and 1947, known as the "Coolidge Reports," made further recommendations which had an influence on the CASS Project. By this time the Boylston Street Subway had been extended west of Kenmore Square. The Huntington Avenue subway had been built, creating the infamous Copley Junction, and some of the eleven surface lines of 1926 had been eliminated.

At the time of the Coolidge Report, the Massachusetts Turnpike had not been built, and the Boston & Albany route from South Station through Back Bay to Riverside via Newtonville consisted of four main tracks. The Coolidge Report proposed extension of the Tremont Street subway via an overpass from the existing portal at Broadway to the two southerly tracks of the Boston & Albany Railroad, and thence along the B&A main route to Riverside. The Boston & Albany Highland Branch to Riverside was to be converted

to streetcar service and connected with the Central Subway as it does today. In addition, the report recommended a branch from Cook Street Junction near Newton Highlands to Needham Junction over the tracks of the New Haven Railroad. This connection would have provided service from Park Street to Needham via Newton Highlands in place of the then existing steam railroad service to Needham via Forest Hills and West Roxbury.

On the Blue Line route, the Coolidge Report recommended extension from Maverick Square to Lynn via the former Boston, Revere Beach, and Lynn railroad right-of-way. Shortly thereafter a portion of this route was constructed as far as Wonderland in Revere, which is the terminal today.

The 1959 Report on Subway Facilities

In 1959 the Metropolitan Transit Authority issued a report regarding "Proposed Subway Facilities Required to Meet Additional Loads from the Prudential and Government Center Projects." This report was transmitted along with a 1958 report of DeLeuw, Cather & Company, entitled "Report Regarding Proposed Stuart Street Subway and Extensions and Alterations to Existing Subways."

This report recommended abandonment of the section of Tremont Street subway between Boylston Street and Broadway. A short piece of this subway was to be retained to make a connection with a new subway passing under Stuart Street to a connection with the Huntington Avenue subway near the Prudential Center. This scheme would have eliminated Copley Junction and provided a subway parallel to the Boylston subway between Exeter and Tremont Streets. Stations were proposed at Clarendon Street and just east of Arlington Street.

Other features of the 1959 proposals were enlargement of Park Street Station and construction of a new subway between Park Street and Scollay Square, parallel to the existing Tremont Street subway. In essence, this scheme would have provided a four-track route from North Station to Boylston Station, from whence two tracks would diverge to Huntington Avenue via Stuart Street and the other two would follow the Boylston Street subway.

The "Myott Plan"

In 1963, Colonel E. B. Myott, then Chief Engineer of the Metropolitan Transit Authority, proposed a ten-year program for modernization of transit facilities and line extensions, which incorporated many of the proposals of earlier studies, but also had some significant differences.

The present South Shore, Haymarket-North, and Southwest extensions were included in the Myott Plan.

Colonel Myott proposed diverting the Riverside Line from the Central Subway and connecting it to the New Orange Line Southwest Extension at Back Bay Station. In the light of today's data on future traffic volumes, it appears that such a scheme would overtax the capacity of the Washington Street tunnel, and result in over-servicing of the Haymarket-North end of the line.

A short extension of the Blue Line was proposed. This was the forerunner of the presently proposed Pines River extension (see Volume IV).

Colonel Myott predicted that when the Prudential and Government Center projects were completed, the Central Subway would be seriously overtaxed. Besides conversion of the Riverside Line to high-platform rapid transit, his scheme called for:

1. Abandonment of all surface car lines, and the East Cambridge viaduct to Lechmere.

2. Buses to replace PCC car service on the Watertown, Commonwealth, Beacon, and Huntington-Arborway Lines.

3. Purchase of 110 low-platform, double-ended shuttle cars for the Central Subway.

4. Short subway extensions under Commonwealth Avenue and Huntington Avenue to new terminal stations with bus transfer facilities.

5. Abandonment of the Beacon Street subway, with Beacon Street service to be provided by buses connecting to the Riverside Line.

TECHNICAL PROBLEMS OF THE CASS PROJECT

By the time the CASS Project was initiated in 1968, the Broadway leg of the Tremont Street subway had been abandoned for several years. Major changes had been made at Scollay Station, now called Government Center. The Massachusetts Turnpike extension and the Prudential Center had been built, and the Boston & Albany Railroad alignment reduced to two tracks. Except for the construction of the Riverside Line and its connection to the Central Subway, none of the other Green Line construction recommended in any of the reports discussed above had been undertaken.

The Riverside Line, which was opened in September 1959, was constructed on a minimum budget and has suffered ever since from substandard service and aging equipment. The routing of this line into the Central Subway, although it gave the patrons good downtown distribution, also added to the congestion and problems of irregularity in the Central Subway. Obviously, the service on the Riverside Line could be much improved by converting it to high-level platform rapid transit type of operation, similar to the Ashmont Line. To do this, however, would require conversion of the entire Central Subway to high-platform operation. This would be impossible without major changes at Government Center, Park Street and Boylston Stations. Furthermore, users of the surface car lines on Commonwealth Avenue, Beacon Street and Huntington Avenue would be forced to transfer before entering the subway, thus losing the benefit of a single-vehicle ride to the downtown area. Expensive transfer facilities would have to be constructed, or the surface lines would have to be abandoned in favor of buses. This was one of the major drawbacks to the "Myott Plan." The transfer requirement would have discouraged patronage and created a type of operation that could not respond well to future demand for increased capacity. Admittedly, it would have been a more efficient system to operate.

Obviously, one way of converting the Riverside Line to high-platform operation without disrupting the rest of the Green Line would be to divert the Riverside Line out of the Central Subway. The imminent construction of the Southwest extension, which would reroute the Orange Line along the New Haven right-of-way via Back Bay Station, coupled with the rapid dwindling of passenger service on the Boston & Albany route, made the B&A alignment from Fenway Park to Back Bay look attractive once again. From an engineering point of view, rerouting of the Riverside Line from Fenway Park to Back Bay via the B&A would be a relatively simple matter. From there the line could connect with the Central Subway via the abandoned segment of the Tremont Street subway or possibly via a Stuart Street subway similar to that proposed in 1958 for the Huntington Avenue Line. In either case, the Riverside Line would avoid the two-track bottleneck between Kenmore and Boylston Stations, and would provide a convenient transfer with Orange Line patrons at Back Bay Station. This scheme would not eliminate Copley Junction but would reduce the number of trains passing through the Junction to a point where the problems would be considerably reduced.

The next logical step would be a connection for high-platform service from Park Street to the Blue Line via Bowdoin Station. Thus, a through route for high-platform service between Riverside

and Wonderland would be created. The remainder of the Central Subway and its related surface lines could still operate with low-level platform service.

The first problem area to come under close scrutiny by the CASS Project, in 1967, was the abandoned leg of the Tremont Street subway from Boylston Street to Broadway and Shawmut Avenue. This section of ab ndoned tunnel was a tempting object for possible re-utilization in connection with improved Green Line service. The new South Cove tunnel of the Orange Line Southwest Extension was about to get under construction. This line was to emerge on the right-of-way of the New Haven Railroad, just east of Back Bay Station. If the Tremont Street tunnel was ever to be extended and utilized in connection with Green Line service via the B&A right-of-way, it was necessary to determine immediately whether it was physically possible to do so without interfering with the South Cove tunnel alignment.

The firm of Parsons, Brinckerhoff, Quade & Douglas, who were participating in the design of the South Cove tunnel, were hired in January 1968 to conduct a preliminary study of possible extension of the Tremont Street subway. In June of 1968, Parsons, Brinckerhoff, Quade & Douglas issued their report which indicated that extension of the Tremont Street tunnel to the B&A right-of-way was feasible. Three different alignments were studied. The recommended alignment preserved as much of the existing tunnel as possible and would have reached the surface at a portal parallel to and just west of the portal of the South Cove tunnel. The preferred scheme had three variations in vertical alignment which varied in cost from $7,690,000 to $8,447,000.

It was also determined that it would be possible to operate the rapid transit cars now in use on the Blue Line through this portion of the existing Tremont Street subway, although the clearances would be extremely tight.

Minor changes in the South Cove tunnel design were made in the portal area to accommodate future construction of the Tremont Street tunnel extension. It was determined that there was sufficient room on the railroad right-of-way for both tunnel portals plus a track to the South Station on the Northerly side of the Tremont Street tunnel portal, and one track on the southerly side of the South Cove tunnel portal.

When DeLeuw, Cather & Company were hired as engineering consultants for the Federally-aided portion of the CASS Project, they were directed to review Parsons, Brinckerhoff's recommendations for the Tremont Street tunnel alignment and their own recommendations of 1958 for the Stuart Street subway alignment.

Because of escalating costs and complications caused by construction of the Massachusetts Turnpike Extension, the proposed Stuart Street subway alignment now looked less attractive than it did in 1958. Furthermore, it would have made use of only a very small portion of the abandoned Tremont Street subway, and would have bypassed Back Bay Station.

There are serious problems at Boylston Station. The station itself is badly in need of modernization. There is a sharp curve where the Boylston Street subway enters the south end of the station. Both main tracks have short reverse curves in the middle of the station. The southbound track leading to the abandoned section of the Tremont Street subway descends an 8% grade into the so-called "sub-subway" to get under the Boylston Street tunnel tracks. At the foot of this grade, there is a reverse curve. DeLeuw, Cather & Company studied a number of alternative schemes for improving Boylston Station, its alignment and grades. It was determined that nothing short of a major rebuilding of the station would provide adequate conditions for modern subway operation. This would require reconstruction of several hundred feet of the abandoned portion of the Tremont Street tunnel, plus a grade separation to get the northbound Tremont Street track over to the westerly side of the Boylston Street Line. These alternatives, coupled with reconstruction required at the Broadway portal, if the tunnel were ever extended, would leave only a short section of the original Tremont Street tunnel structure intact. Reconstruction of Boylston Station would be greatly simplified if the Tremont Street tunnel could be eliminated completely. The curve at the south end of the station could then be eased considerably without having to destroy the tunnel structure.

Because of the foregoing considerations, plus the fact that the proposed Stuart Street alignment would have no interchange with the Orange Line at Back Bay Station, DeLeuw, Cather determined that a preferable route for the Riverside Line from Back Bay to Park Street would be via a new subway connection under the Turnpike along Columbus Avenue to Park Square, and under Boston Common to Park Street Station. The line could either be terminated there or extended to a connection at Bowdoin. This alignment would have the added advantage of a station near Stuart and Eliot Streets, which would serve the rapidly growing Park Square district. Such a subway could be constructed to modern Red Line standards with ample clearances. Most of the portions under Boston Common could be constructed by bored tunneling methods without disturbing surface activities, and there would be little interference with existing operations during construction. The total cost of this alignment is estimated to be little more than the combined cost of extending the Tremont Street Subway to the railroad right-of-way, plus reconstructing Boylston Station under traffic.

A number of possible ways of connecting the Riverside Line to the Blue Line were explored by the CASS Project. Among the schemes which were rejected was a direct connection from the Tremont Street subway to the Blue Line between State Street and Government Center. Construction of such a connection was not feasible and had many disadvantages. Another consideration was a semi-circular loop tunnel, connecting the Green Line just north of Haymarket Station with the Blue Line at Bowdoin. Major construction in the Government Center area has made such a loop impractical. Furthermore, it would require trains running between Riverside and Wonderland to pass through Government Center Station twice: once on the upper level, and once on the lower level. Abandonment of the Bowdoin Extension could not be seriously considered as it was in 1926, because of recent renewal and reconstruction in the Government Center area. Therefore, the only feasible Blue-Green connection was the Park to Bowdoin tunnel passing under Beacon Hill.

As mentioned above, rerouting of the Riverside Line from Fenway Park to Back Bay does not eliminate Copley Junction. The Authority's staff and the consultant have studied ways of improving signaling and control at this junction. A remotely-controlled interlocking plant with route selection being made by a system of automatic train identification would form a part of a modernized signal and control system for the entire line. Such a system would do much to alleviate conditions at the junction. Various schemes for improving operations at the location are discussed elsewhere in the report. Rebuilding the junction to create a grade separation between the outbound Huntington Avenue tracks and the Boylston Street tracks was also considered and rejected as too complicated and costly.

The ultimate cure, of course, would be elimination of the junction. This could be achieved by rerouting the Huntington Avenue Line so that it would emerge from its subway just west of Back Bay Station and follow the B&A right-of-way, either on it or under it, through Back Bay Station to a connection with the Tremont Street subway as described earlier for the Riverside Line. An alternative would be to continue on into South Station. If the Riverside Line as well as the Huntington Avenue Line were rerouted via the B&A right-of-way, this would have the disadvantage of creating a new junction just west of Back Bay Station. There would also be the problem of operating both high level and low level cars through Back Bay Station and into Park Street on the same tracks. The rerouting of the Huntington Avenue Line could better be accomplished if the Riverside Line were to remain in the Central Subway.

As discussed previously, however, this would require the Riverside Line to remain a low level platform operation or the Central Subway would have to be converted to high platforms.

One of the main problems involved with the use of the B&A right-of-way is that the Penn Central's present and projected operations require the use of at least one track. There are now only two tracks from Back Bay Station to Riverside and beyond. Where the line passes through the Prudential Center, it would be impossible to widen the right-of-way for an additional track. Therefore, under present conditions the Authority could hope to get the use of only one track between Back Bay and Fenway Park. This is a distance of over 6,000 feet and single track operation for rapid transit service for this long a stretch would be quite difficult. East of Back Bay Station, however, as far as South Station, it would be possible to provide rapid transit service and still allow for B&A operations. The Huntington Avenue Line could therefore be rerouted to the Tremont Street subway or to the South Station, or both, without eliminating B&A railroad operations.

The Engineering Consultant, DeLeuw, Cather & Company has explored these various possibilities in some depth. They are discussed in Volume II of this report.

Another possibility considered by DeLeuw, Cather & Company was elimination of rail car service in the Huntington Avenue subway and substitution of buses, or possibly dual-mode vehicles, at some future time. Buses would make use of the existing Symphony and Prudential Stations and then emerge from the subway to a transfer facility with the Riverside and Orange Lines at Back Bay Station.

Of the five lines that enter the Central Subway, one, the Riverside Line operates entirely on private right-of-way; two lines, the Commonwealth Avenue and Beacon Street Lines operate on median strips; the Huntington Avenue-Arborway Line operates partially in median strip and partially in the street; the Watertown Line operates entirely in the street up to the point where it joins the Commonwealth Avenue Line. The Riverside Line, which was formerly the Highland Branch of the Boston & Albany Railroad, is grade-separated for its entire length. The curves are reasonable and it has good potential for development into a high-speed rapid transit operation.

The Beacon Street Line operates in subway from Kenmore Square to St. Mary's Street and in median strip from there to its terminus

at Cleveland Circle. The Commonwealth Avenue Line emerges from the subway just west of Kenmore Square and operates in median strip to its terminus near Boston College. Both of these lines are subjected to some interference from cross traffic at intersections. The median strips vary in width but are adequate for the entire length, and in some areas are quite wide and attractive.

The Huntington Avenue-Arborway Line operates in subway from Copley Junction to the portal at Northeastern University. From there it operates in a very narrow median strip on Huntington Avenue for about a mile to Brigham Circle, and from that point on operates entirely in the street to Forest Hills via South Huntington Avenue, Centre Street and South Street. This line constantly encounters serious interference with vehicular traffic and pedestrians. Even in the segment between Northeastern University and Brigham Circle, the median strip is so narrow that passengers have to board and alight in the street at some stops and interference with vehicular traffic and pedestrians is greater than on Commonwealth Avenue and Beacon Street.

The Watertown Line utilizes the Commonwealth Avenue tracks from the subway portal for about a mile and a half to Packard's Corner. From there the line operates entirely in the streets following Brighton Avenue, Cambridge Street, Washington Street, Tremont Street, and Galen Street to its terminus near Watertown Square. From Packard's Corner out, the line suffered from the same problems of traffic congestion that plague the Arborway Line. Revenue service on the Watertown Line was recently discontinued on an experimental basis in favor of buses. The buses follow the same route as the surface cars, running express between Packard's Corner and Kenmore Square, where transfer is made to the Central Subway.

One of the major tasks of the Authority's staff and consultants under the CASS Project has been to explore ways of improving the speed and regularity of service on the surface lines which feed the Central Subway. Traffic-related delays which occur on the surface are reflected in irregular headways in the subway. This causes bunching of trains and gaps in service, both in the subway and on the surface.

Prior to the approval of the Federal Grant for CASS, the firm of Bruce Campbell & Associates carried out a number of traffic engineering studies for the Authority, and in May 1969 submitted a report on the Beacon Street Line which recommended a large number of minor improvements designed to reduce loading and unloading times and improve regularity and safety. Although a

similar detailed study has not been made for the Commonwealth Avenue Line, many of Bruce Campbell's recommendations for Beacon Street could be applied in principle to Commonwealth Avenue. Many of the recommendations are concerned with better control of street traffic and pedestrians, and their implementation will therefore require close coordination with the City of Boston and the Town of Brookline. In some cases, methods of joint funding will have to be worked out.

Regarding the street running portions of the Watertown and Arborway Lines, there is little hope of achieving any significant improvement in performance, traffic conditions being what they are. In fact, performance can be expected to deteriorate as the streets become more and more congested. The flexibility of buses and their ability to maneuver through traffic and around temporary obstructions makes them far superior to streetcars for this type of operation. This has already been demonstrated by the dramatic reduction in the number and length of delays on the Watertown Line since buses were adopted. It seems inevitable that buses will have to replace streetcars on the Arborway Line, at least from the Heath Street Loop on out. As part of the CASS Project, Authority staff has been exploring the feasibility of a surface terminal for the Huntington-Arborway Line, somewhere between Brigham Circle and Heath Street. It is not expected that such a terminal would provide for any maintenance facilities or for any great amount of car storage space, but it would provide a convenient transfer facility for bus passengers to the surface car line.

In 1968 the Authority staff and the Boston Redevelopment Authority jointly prepared a plan for the widening of Huntington Avenue from the portal to Brigham Circle. This plan provided for a very adequate median strip, a better track alignment and fewer cross streets. It has not yet been implmented due to lack of funds, but is urgently needed to improve conditions on this stretch of Huntington Avenue. As this chapter is being written, the City of Boston Traffic and Parking Department is preparing to submit an application to the U. S. Bureau of Public Roads for funding of this project under the TOPICS Program (Traffic Operations Program to Increase Capacity and Safety).

VEHICLE MAINTENANCE FACILITIES

A very critical problem with the Green Line is caused by the vehicle maintenance facilities. As the surface car lines have been cut back over the years, these facilities, and the access to them, have become fewer and fewer. It is now not possible

for Green Line cars to reach the main shops at Everett by rail. When heavy repairs are required, these cars have to be trucked by means of a flat-bed trailer from the Lechmere Square terminal to the Everett Shops. Obviously, this type of operation is avoided as much as possible, and Green Line cars are sent to Everett only for complete overhauls or major rebuilding jobs.

There are existing maintenance facilities at the outer ends of both the Watertown Line and the Arborway Line. Therefore, neither of these lines can be permanently cut off until an alternate location is found for carrying on the remaining maintenance operations. With Watertown and Arborway gone, the only remaining maintenance facility would be the Reservoir Shop near Cleveland Circle. The Reservoir Shop is located adjacent to both the Riverside Line and the Beacon Street Line. It is also connected with the Commonwealth Avenue Line by means of a short stretch of track on Chestnut Hill Avenue. This shop is well located from the maintenance point of view, but is severely cramped for space. Unfortunately, it is located in a residential area and is therefore "an unwelcome neighbor." The Authority could not seriously consider any major expansion of the Reservoir facility. Nevertheless, it would be impossible for this facility to absorb the workload remaining after the discontinuance of either the Watertown or Arborway Shops.

A major new facility for the Green Line is needed, and investigation has shown that the only feasible location for such a facility is on Authority-owned land at the Riverside Terminal. The Authority plans to acquire a fleet of new high-performance surface rail cars, and it would be most difficult and unwise to attempt to maintain them with the antiquated facilities at Reservoir. Until a new shop is built and placed in service at Riverside, little progress can be made in overcoming the maintenance problems of the Green Line. When this shop is ready for service, major improvements can be made at the Reservoir facility, and the Watertown and Arborway facilities can be closed.

One of the apparent benefits of the proposed connection between the Riverside Line and the Blue Line (between Park Street and Bowdoin), discussed earlier in this chapter, would be the availability of the Orient Heights Shop for maintenance of Riverside cars. The Orient Heights Shop was constructed when the Blue Line was extended in 1952, and is presently the most modern shop on the system. All of the Blue Line cars are maintained at Orient Heights. Unlike Reservoir, Orient Heights has ample space for present operations, and with some modifications could probably handle maintenance on the additional cars that would be required

for a high-level platform type operation of the Riverside Line. If Riverside and Blue Line cars were to be maintained at Orient Heights, it is then possible that an improved and renovated Reservoir Shop could handle maintenance on the remaining low-level platform cars which would be required to service the Central Subway, Beacon Street, Commonwealth Avenue, and a shortened Huntington Avenue Line.

The CASS study has shown that there is no immediate need for a Riverside-Blue Line connection, and the conversion to high-platform operation that would be necessary. Neither is there any likelihood of funds for such a conversion becoming available in the immediate future. On the other hand, the need for new Green Line maintenance facilities is critical. We cannot expect Orient Heights to be a factor in easing this critical problem in the foreseeable future. Consequently, the construction of a new shop at Riverside is imperative.

It might be argued that conversion of the Beacon Street and Commonwealth Avenue Lines to bus operation could ease the load on the Reservoir facility to the point where no new shop would be required after the Watertown and Arborway shops are closed down. However, the large fleet of buses that would be required to replace the electric car service on these routes would necessitate additional bus maintenance facilities at some location. The buses on these routes would add to the congestion of the street traffic, whereas the rail cars operate on their own median with little interference. Conversion to buses would require additional transfer facilities at Central Subway portals, and the operating manpower requirements would be increased. The ability of the rail cars to operate in trains of three or more cars provides considerably greater line capacity than a bus route could provide. Operation of buses on the median strips has been suggested, but this presents problems of traffic control and enforcement of the exclusive right-of-way. Furthermore, in view of the present public attitude towards noise and air pollution, any plans for conversion to buses on these lines would surely meet with strong local opposition.

PLATFORM HEIGHTS

Realizing that it may not be possible to divert the Riverside Line out of the Central Subway, DeLeuw, Cather & Company was directed to explore the feasibility of conversion of the Central Subway to high-platform operation. This was done in spite of the undesirable transfer situations that would be created for

the surface lines. Although conversion is possible and may some day be required to provide capacity, it presents many technical problems, most of which are caused by the configuration of existing subway stations. High-platform operation on the surface of Huntington Avenue would be impossible and this line would have to terminate at Symphony, or the subway would have to be extended further out Huntington Avenue. The possibility of converting the Commonwealth and Beacon surface lines to high-platform operation in order to avoid transfer problems was considered. While not impossible, this type of operation on the median strip would be difficult to achieve. The median strip is too narrow for high-platforms at many of the existing stops. It would be impractical to maintain prepayment facilities at each of the stops. On-board fare collection would require additional manpower unless an automated and unsupervised system is developed which is not now available. On-board fare collection with high-level platforms and one man per car is done in Cleveland at certain stations in the off-peak hours, but conditions here are somewhat different from Cleveland. This type of fare collection would require new high-level platform cars to be designed for operation with one man per car. This would largely negate one of the inherent advantages of high-level platform vehicles, i.e., trains of almost any length can be operated with a minimum crew.

The Authority's Equipment Engineering and Maintenance Department has prepared preliminary designs for a new series of low-level platform cars which should perform much better than the present PCC cars in the Central Subway and on the Riverside Line. They would also operate efficiently in the lower speed stop-and-go service on the other Green Line surface routes. This car design, known as the No. 6 car, is discussed in more detail in Chapter 10. The Authority is also investigating various types of European tram cars, including one that has movable steps that will adapt to either low or high platforms. There is a variety of modern rail-car types which are operating successfully in various European cities, some of them under conditions quite similar to Boston.

RIVERSIDE VIA HUNTINGTON AVENUE

Turning again to the Huntington Avenue Line whose problems were discussed above, we note that near the intersection of Huntington and South Huntington Avenues, the linecomes within about a thousand feet of the Riverside Line at Brookline Village. DeLeuw, Cather was directed to study the feasibility and cost of connecting the Riverside Line with the Huntington Avenue Line by means of an overpass or a subway from Brookline Village Station to

Huntington Avenue. They were also directed to study the extension of the Huntington Avenue subway from its present portal through Brigham Circle to link up with this Riverside connection. If this were done, Riverside trains would then be routed downtown from Brookline Village via the newly extended Huntington Avenue subway. On the intown end, Copley Junction would be eliminated and the line rerouted via the Penn Central right-of-way through Back Bay Station, and thence to the previously described Columbus Avenue subway, or to an extension of the Tremont Street subway. In the existing Central Subway, only Symphony and Prudential Stations would have to be converted to high platforms. Service between Brookline Village and Kenmore Station could be maintained over the old route using low-level platform shuttle trains.

The routing of Riverside trains via the Huntington Avenue subway could produce a Riverside-to-Wonderland route for high-level platform service without interfering with Penn Central Railroad operations on the Boston & Albany route. It would have the advantage of an interchange with the Orange Line at Back Bay Station and it would eliminate Copley Junction. Its main disadvantage is that it is the most expensive of any of the schemes studied. Extension of the Huntington Avenue subway from Northeastern University to Brookline Village has been estimated by the engineering consultant to cost about $41 million. Three major points of interference, which would require a deep subway, occur at the Stony Brook Conduit near Parker Street, the proposed Inner Belt near Ruggles Street, and the Muddy River on the Boston-Brookline boundary. See the discussion of System 3 in Volume II.

If the rerouting of the Orange Line via the Boston & Providence right-of-way is accomplished as is planned under the Southwest Extension project, the proximity of this new line to the Huntington Avenue subway raises some doubts as to the advisability of so large an expenditure on the Huntington Avenue Line. Undoubtedly, some Huntington Avenue local riders will be attracted to the new Orange Line. On the other hand, the loss of local riders would not be inconsistent with the function of the new Huntington Avenue subway as it would be serving more as a through access route for Riverside passengers to downtown than it would as a local distributor. Chapter 9 discusses the impact that such a subway would have on local Huntington Avenue riders.

THE CLEARANCE PROBLEM

Another serious problem area which affects the entire MBTA system, but most of all the Green and Blue Lines, is the matter of limited clearances.

The Tremont Street portion of the Central Subway was opened in 1897 and is the oldest subway in North America. It was designed for trolley cars, not rapid transit trains. The Boylston Street portion of the subway from Charles Street to just east of Kenmore Square was opened in 1914 and was constructed with ample clearances and reasonable curves so that it could accommodate full-size rapid transit trains similar to those used on the Cambridge subway. Kenmore Station and the subway extensions out Commonwealth Avenue and Beacon Street were opened in 1932. The Huntington Avenue portion of the subway was built in 1940. The most critical clearance problems occur in the oldest portion of the subway between Haymarket Station and Boylston Station. In this section, the most serious limitations occur at the curve under Hanover Street, through Government Center Station (southbound), the tunnel section between Government Center and Park Street Stations, Park Street Station southbound, and the curve at the south end of Boylston Station. There are four tracks in the subway between Boylston and Park Street so that clearance problems are not serious in that section.

The Blue Line has clearance problems similar to the Green Line. It too was constructed as a trolley car subway. This line, which includes the East Boston tunnel under Boston Harbor, was opened for service from Court Street to Maverick Square in East Boston in 1904. In 1916, an extension to Bowdoin was built to provide a loop for quick turn-around of the East Boston cars. In 1924, this line was converted to third-rail operation and high-level platforms. In the early 1950's, the East Boston end of the line was extended from Maverick to Orient Heights and to Wonderland, Revere, following the route of the old Boston, Revere Beach and Lynn narrow guage railroad.

Any enlargement of the East Boston tunnel is out of the question. Therefore, if the Blue Line is ever extended to form a connection with the Riverside Line or any other line, the size of the cars will necessarily be limited to approximately that of the present Blue Line cars. These cars are 48'6" long and 8'7" wide. This is approximately the same overall dimensions as the PCC cars presently operating in the Central Subway. The square profile and greater height of the Blue Line cars, however, require a slightly larger clearance envelope than the PCC cars. Nevertheless, the previously discussed connections between the Green Line and the Blue Line would be feasible as far as clearances are concerned without major reconstruction of existing tunnels.

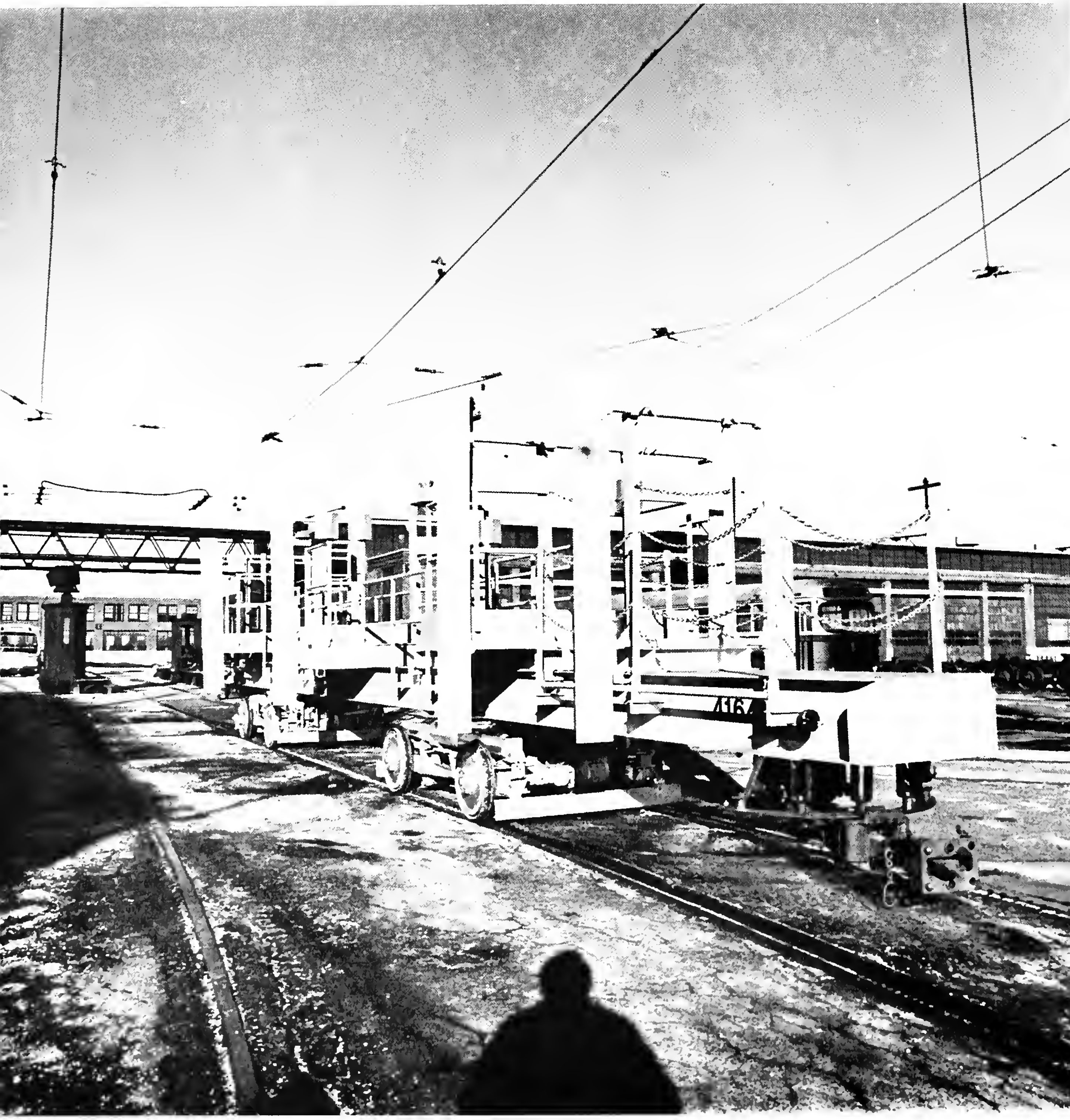
It would be desirable to operate the Riverside Line, or any new or rebuilt line, with the largest cars possible in order to

conserve manpower, but if a through route is the objective, a Green-Blue connection is the most logical. Nevertheless, the engineering consultant, DeLeuw, Cather & Company, in estimating the conversion of the Riverside Line to high platforms was instructed to plan for clearances and curvature that would be compatible with the largest cars used by the Authority, those on the Red Line. The Red Line cars are 69'6" long and 10'4-1/4" wide. They are among the largest rapid transit cars in use anywhere in the world. It is the Authority's policy that all new construction and facilities be designed to accommodate cars of this size wherever this can be achieved at reasonable cost.

Smaller than the Red Line cars, but larger than the Blue Line cars, are the Orange Line cars which are 55' long and 9'5-1/2" wide. Their size is limited by the Washington Street tunnel which was opened in 1908. Construction of this tunnel presented special engineering problems due to the narrowness of Washington Street.

As part of the CASS Project, a clearance test vehicle was constructed at the Everett Shops, and measurements have been made throughout the Central Subway to confirm earlier calculations as to the maximum size of new vehicles that can be operated through it without major alterations. These tests have confirmed that the new low-level platform vehicles now under design can be operated through the subway with only minor structural alterations to the subway. These cars are to be 50' long and 8'8" wide. Figure 8-1 is a picture of the clearance test car.

Due to the clearance limitations of the Orange, Blue and Green Lines, the Authority must maintain a separate fleet of vehicles for each of the four lines and cannot take advantage of economies that would accrue from a single fleet of vehicles and a common pool of spares. Although the tunnels of the four lines--Red, Orange, Blue, and Green--intersect each other in a small area in the Central Business District, they are at different levels and there are no physical track connections from one line to any of the others. Methods of interconnecting the four lines with each other have been studied, but in the Central Business District, difference in levels of the tunnels combined with the large buildings in the area, make any such connections completely impractical. Even if such connections were feasible, it would be impossible to operate the cars of one line in revenue service on another line, due to the differences in platform height and spacing. Again, because of clearances, Red Line cars could not operate in the Orange Line tunnel, nor could Orange Line cars operate in the Blue Line tunnel. It might be possible to operate



Clearance Test Car

FIGURE 8-1

Blue Line cars in revenue service in Orange Line territory by shimming up the car bodies 3" and building up the Blue Line platforms by a corresponding amount. The differences between Orange Line and Red Line platforms are too great to make any such adjustment possible. The value of connecting any of the existing lines together therefore would only be to permit moving vehicles to a central point for maintenance and repairs.

It would be easy to make a connection between the Green and Orange Lines, near Haymarket Station. Such a connection could permit moving Green Line equipment to the new Wellington Shops of the Orange Line, which are to be constructed in Medford. It must be remembered, however, that the Green Line uses overhead power distribution whereas the Orange Line uses third rail. Therefore, Green Line cars would have to be towed, or overhead wire would have to be installed in the areas where these cars would operate. Furthermore, it is not known whether the under-body structure of the new low-level Green Line cars will be such that they would clear the third rail if they were to be operated or towed in third rail territory.*

Another good possibility for interconnecting Green and Orange would occur near Back Bay Station, if any portion of the Green Line is rerouted via the Boston & Albany right-of-way. A connection could then be made just east of Back Bay Station with the new Orange Line near where it will emerge from the South Cove tunnel. From this point, trackage could be extended into the South Station and a connection made from there to the Authority's planned Red Line shop facility in the South Bay area. Such connections would be most useful for the Green Line if and when all or part of it is converted to high-platform operation.

If the previously discussed tunnel connection between Park Street and Bowdoin is built, interconnection would then be accomplished with the Blue Line.

As this is written, construction plans for the Orange Line Southwest Extension have been held up pending a restudy of major highway

*If it is ever planned to use some of these new cars on the Mattapan high-speed trolley line, this lack of clearance for third rail would be a serious problem. Improvements to the Mattapan Line are not within the scope of the CASS Project.

construction in the Metropolitan area. Meanwhile, the first link in the Southwest Extension, the South Cove Tunnel, has been partially completed. If it should be eventually decided not to go forward with the Southwest rail extension, it would be quite feasible from an engineering point of view to complete the South Cove Tunnel and operate Orange Line equipment through to Riverside via Back Bay Station and utilizing either the Huntington Avenue subway or the B&A right-of-way, as previously discussed. Failure to construct the Southwest Extension, however, might mean that the existing elevated line to Forest Hills via Washington Street would be continued in operation. It is doubtful whether the Washington Street tunnel stations could handle the predicted traffic fed in by both the elevated line and the Riverside Line.

THE LECHMERE LINE

A final problem area of the Green Line is the Causeway Street elevated structure and the viaduct to Lechmere Square in Cambridge.

Just north of Haymarket Station, the Green Line emerges from the Central Subway and splits into two branches; one terminates in a surface loop and station at the intersection of Canal Street and Causeway Street; the other continues up an incline to an elevated structure which follows Causeway Street and Lowell Street to Leverett Circle, and thence to Lechmere Square in Cambridge via a concrete arch viaduct over the Charles River Dam. After completion of the Orange Line extensions, the Causeway Street structure will be the only remaining elevated line on the system. There has been much local pressure on the Authority to eliminate this structure, which has a blighting influence on the neighborhood. One of the worst features is the loud squealing of flanges as the streetcars negotiate the sharp curves at Canal and Lowell Streets.

The possibility of a subway connection between Haymarket Station and the concrete viaduct structure at Leverett Circle has been investigated. A relocated elevated structure at Leverett Circle has been investigated. A relocated elevated structure was also considered which would have carried the line down Accolon Way and across the Boston & Maine Railroad Station tracks to a connection with the viaduct at Leverett Circle. Although this would be less expensive than a subway connection, there is little popular appeal in substituting one elevated structure for another. Although the subway link was found to be physically feasible, its cost could not be justified in the light of present volumes on the Lechmere Line and the relatively short distance to the terminal in Cambridge.

It would be possible to terminate all Green Line operations at the Canal Street surface loop, provided some additional storage tracks were installed and other alterations made. The Causeway Street structure could then be demolished and the concrete viaduct to East Cambridge could be rebuilt as an exclusive busway with a ramp down to the surface streets. Buses could then bring passengers in from Somerville and Cambridge to a transfer facility at the Canal Street surface station. Such a scheme was investigated and found to be feasible (see Volume II). The City of Boston, however, does not wish to encourage bringing in any additional buses into the downtown area. This also runs counter to the Authority's general policy of extending rapid transit routes and using bus lines as feeders to the outer terminals.

If future growth in the Cambridge-Somerville area provides sufficient demand for downtown trips to justify the extension of the Green Line beyond Lechmere (perhaps via portions of the Boston & Maine right-of-way), then a tunnel connection to eliminate the Causeway Street elevated structure could probably be justified.

The Authority is now participating in studies with the Cities of Cambridge and Somerville to determine their future need for downtown-oriented transit service. Until this need is clarified, the elevated structure will have to remain. There will be no problem, however, in operating the new low-level cars over this structure, nor would there be any great difficulty in converting the structure for high-level platform operations. Platforms would have to be raised and lengthened at North Station-West, Science Park, and Lechmere terminal.

From an engineering point of view, therefore, the continued existence of the Lechmere Line and the Causeway Street elevated are no impediment to the adoption of any of the other improvements to the Green Line which have been discussed.

One final thought regarding the relative merits of high-platform and low-platform operation--Massachusetts law currently requires that rapid transit trains be operated with a guard for every two cars. This is in addition to the operator of the train. Therefore, for short trains there is little or no saving in manpower for high-platform operation as compared to low-platform. Low-platform operation requires a man on every car for operating doors and fare collection on the surface. If the current law should ever be repealed and traffic volumes increased to require longer trains, the economies of high-platform operation would look much more attractive than they do today. The technology exists right now to operate high-platform trains with no crew at all.

CHAPTER 9

ALTERNATIVE DOWNTOWN SYSTEMS EVALUATED

Preceding chapters have set the research of the Central Area Systems Study into a regional perspective. In Chapter 8, we narrowed down to a discussion of specific engineering solutions for the downtown or Central Area, designed to unplug the bottleneck which is preventing all segments of the Green Line from providing the dependable service of which they could be capable.

The CASS Project studied these engineering improvements in detail and combined them to form several alternative systems for further analysis. Three principal systems were selected for detailed testing. They are described in the following pages. Volume II of this report contains the engineering consultant's detailed studies and construction cost estimates for these alternative systems. The traffic consultant, Peat, Marwick, Mitchell & Co., provided traffic forecasts for these same systems. The Authority staff has analyzed the results of PMM's work. This chapter describes and summarizes the work which was undertaken in determining the impact of the various downtown alignments for the Green Line, and provides a background for the study of other improvements to the Green Line. The alternatives have been extensively reviewed in terms of the Riverside Line, but this has not excluded consideration of the associated services which are provided to the entire Western Corridor and other corridors. Analysis has been based on the performance of alternatives within the framework of the entire MBTA rapid transit system.

This chapter is presented in three Sections and an Appendix.

Section A summarizes an extensive traffic analysis of three "total systems" created for the downtown area. These systems are compared in terms of their performance levels against the "base" system with present performance data. This first section is created to show the variations of system performance possible under differing conditions.

Section B analyzes the three systems in terms of their component parts, and the feasibility of implementation of each of these parts. The level of benefit in terms of the cost of implementa-

tion is discussed. Using data developed in the traffic analysis section, this part of the chapter undertakes to determine which elements of various systems are worthy of implementation and which must be discarded from further consideration.

Section C presents the recommended planning program for the downtown routing of the Riverside Line, based on the information presented in the previous sections of this chapter.

The forecasting methods used are described in the Appendix to this chapter.

SECTION A

A DETAILED TRAFFIC ANALYSIS OF THREE POTENTIAL 1990 DOWNTOWN SYSTEMS

Perhaps the most salient factor of traffic analysis is the need to examine total systems, even when few component parts are actually proposed for alteration. Out of this consideration, the traffic analysis program of the Central Area Systems Study created three basic hypothetical 1990 systems for extensive testing. By necessity, analysis proceeded on the total system level, which revealed clearly the function of the specific component parts of each network.

This section presents a series of summary tables which describe characteristics of the three systems studied.

DESCRIPTION OF THE SYSTEMS

Systems which were analyzed by the consultant, Peat, Marwick, Mitchell & Co. (PMM) are designated 1990 Systems 1 through 3. The following is a description of each of these systems.

1990 System 1

Green Line (low-level service) operates through the Central Subway from Heath Street, Cleveland Circle and Boston College terminals to North Station terminal (Canal Street).

Riverside Line is converted to high-platform service between Riverside and Wonderland terminals with a new connection between Park and Bowdoin Stations. The Riverside Line is

rerouted from Fenway to Back Bay via the B&A right-of-way, thence via Columbus Avenue and under Beacon Hill to Bowdoin Station. New downtown stations on the Riverside Line are located at Massachusetts Avenue, Back Bay, Eliot, Park Street and on to Bowdoin Station.

Orange Line is rerouted from its present alignment as currently planned. New downtown stations will be located at Massachusetts Avenue, Back Bay, and South Cove.

1990 System 2

Green Line (low-level service) operates through the Central Subway from Brookline Village, Cleveland Circle, and Boston College terminals to North Station terminal (Canal Street).

Riverside Line converted to high-platform service between Riverside and Wonderland terminals with a new connection between Park and Bowdoin Stations. Riverside Line is rerouted from Brookline Village to Brigham Circle and enters downtown via extended Huntington Avenue Subway to Back Bay, under the B&A right-of-way and Massachusetts Turnpike, thence via Columbus Avenue Subway and under Beacon Hill to Bowdoin Station. New downtown stations on the Riverside Line are located at Symphony, Prudential, Back Bay, Eliot, Park Street, and on to Bowdoin Station.

Orange Line is the same for all systems

1990 System 3

The Riverside Line remains routed through the Central Subway as now, but with a new tunnel connecting from just east of Arlington to Park Street Station (bypassing Boylston Station), and under Beacon Hill to Bowdoin Station.

The Riverside Line and the portion of the Central Subway from Kenmore through Arlington are converted to high-platform service.

The Huntington Avenue Line remains low-level service and is routed into the Broadway portal of the Tremont Street subway via Back Bay Station, and on to North Station (Canal Street) via Boylston, Park, Government Center and Haymarket.

The Commonwealth and Beacon Lines remain low-level service and turn back near Kenmore with transfer facilities to the Central Subway.

Orange Line is the same for all systems.

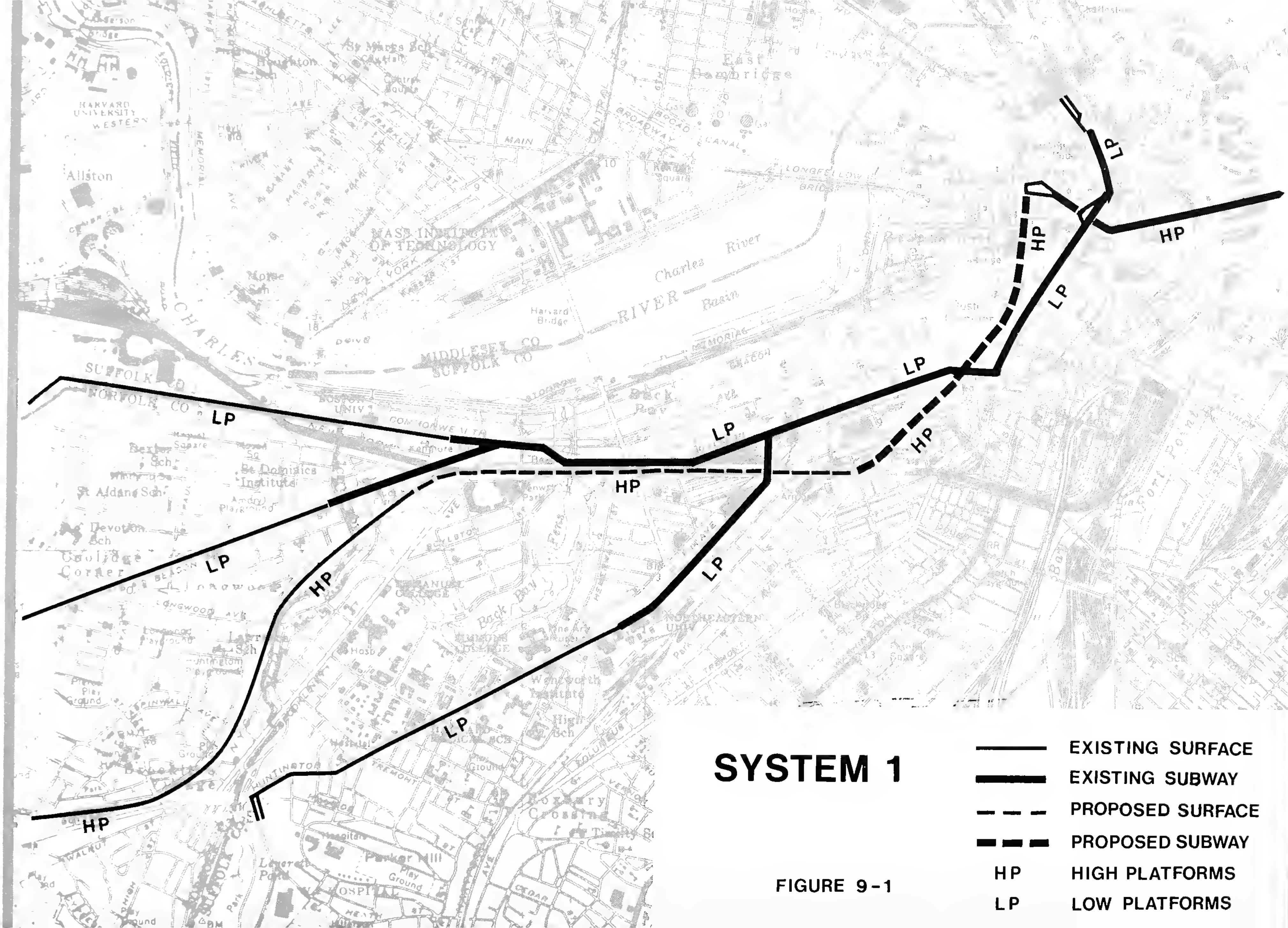
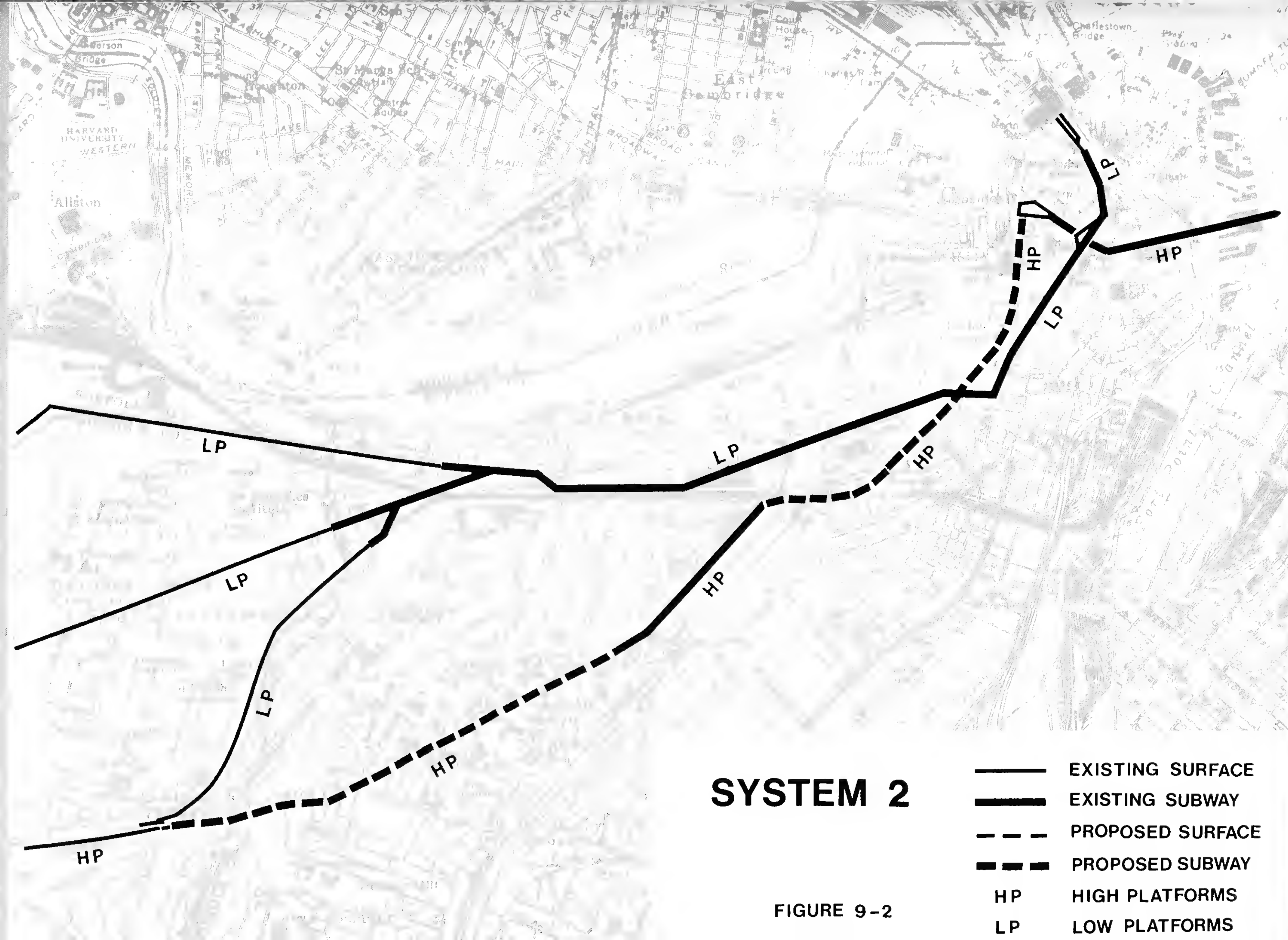
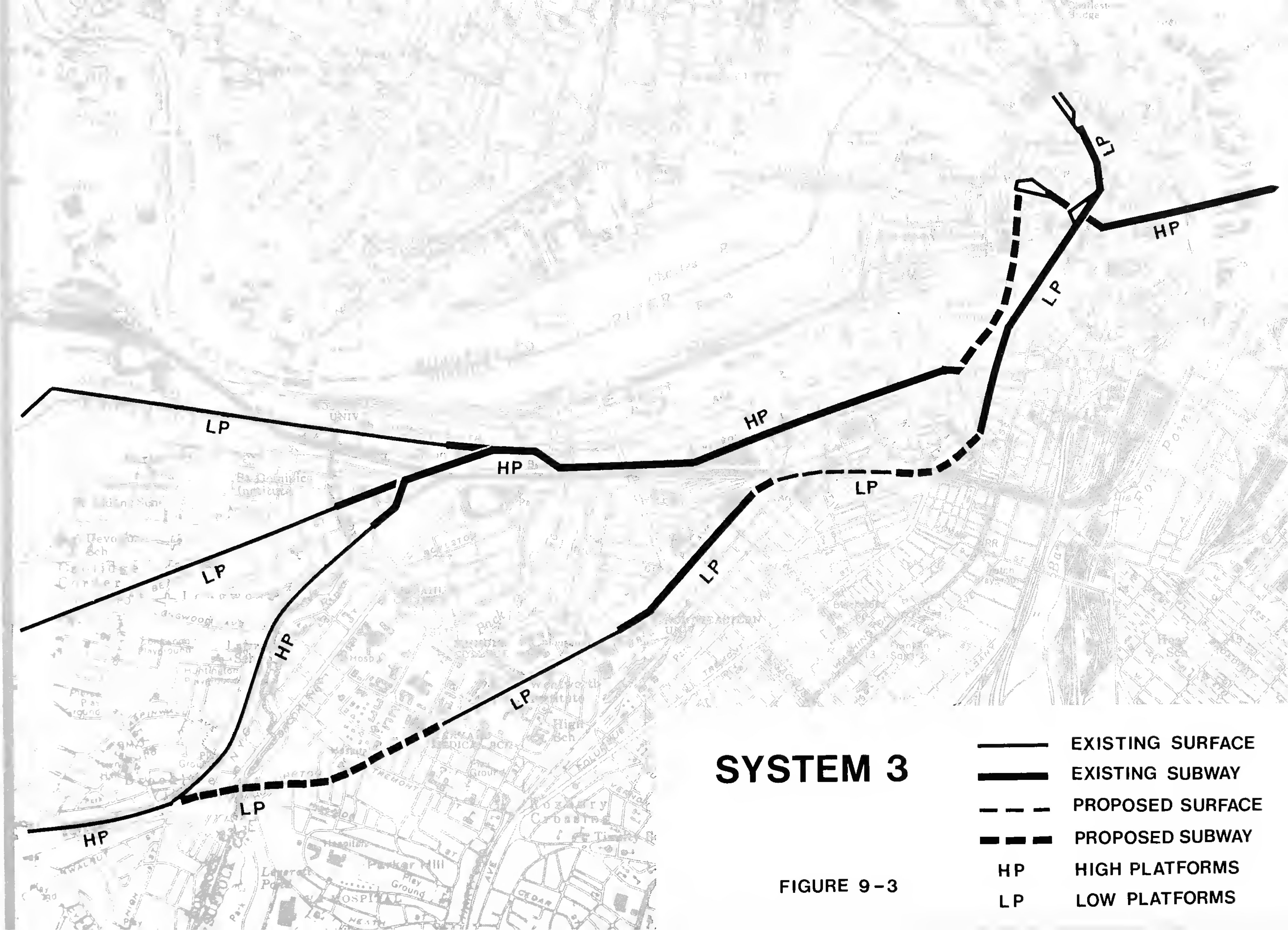

SYSTEM 1
EXISTING SURFACE
EXISTING SUBWAY
PROPOSED SURFACE
PROPOSED SUBWAY
HP HIGH PLATFORMS
LP LOW PLATFORMS
HP
LP
Charles River Basin
MASS INSTITUTE OF TECHNOLOGY
East Cambridge
Allston
Coolidge Corner
Harvard Bridge

FIGURE 9-1



SYSTEM 2
EXISTING SURFACE
EXISTING SUBWAY
PROPOSED SURFACE
PROPOSED SUBWAY
HP HIGH PLATFORMS
LP LOW PLATFORMS
HP
LP
HP
LP
HP
HP
LP
LP
LP
LP
HP
HP
Charlestown Bridge
East Cambridge
Allston
HARVARD UNIVERSITY WESTERN

FIGURE 9-2



SYSTEM 3

FIGURE 9-3

In addition to the three basic 1990 Systems, other extensive computer runs were made for comparison purposes. These include:

A Base System with 1990 Loadings

This system was run in order to provide data comparative with the systems under analysis. It provides a base from which to measure the performance of the other systems in terms of passenger distribution and travel time. It is essentially a "do-nothing" system for the Green Line, as it assumes no new alignments downtown nor conversion to high-platform service for that line. The Orange Line is the same as for the other systems.

It is important to note that in order to compare future systems with actual present conditions, 1968 running times were used. Therefore, Base System data does not use the same vehicle performance characteristics for the Green Line as other 1990 systems, which assume high performance equipment throughout.

System One - Modified

In order to determine the impact of the Blue-Green connection (between Park and Bowdoin), it was necessary to run a similar system without the new tunnel. For this reason, System One - Modified runs the Riverside Line over the B&A-Columbus Avenue route to a Park Street terminal.

System Three with Split Service

An experiment was undertaken to determine the effectiveness of a Riverside service that splits at Arlington, with one-half of the service going to North Station (Canal Street) with the other half going to the Blue Line connection (both branches high-level service). Traffic analysis showed virtually no benefit in this concept, and it was discarded from further consideration. It did, however, feature a Huntington Avenue to South Station connection, the relevant data about which is reported in the text.

A large number of variations and sub-alternatives are possible by putting together different components of the three systems. Many were considered, but did not appear to have sufficient merit to warrant computerized testing.

By the use of "convertible" cars, able to adapt to either high or low platforms (see discussion in Chapter 10), a number of

variations of System 3 would be possible, such as high platforms in the Central Subway with low platforms on the surface lines and through service on all lines.

STATISTICAL SUMMARY - COMPARISON OF SYSTEMS

Table 9-1 illustrates the downtown boardings for Systems 1, 2, 3 and Base. Station boardings for Systems 1 and 2 differ only slightly. The main differences occur at Prudential, Symphony and new Eliot Stations where the volumes are notably higher for System 2 as a result of combining the Riverside and Huntington Lines. System 2 provides a useful function by creating increased use of Prudential and Symphony Stations which show little use in the other systems. Systems 1 and 2 reduce Central Subway congestion in reducing boardings at Boylston, Arlington and Copley by one-half. The new Eliot Station, with 10,000 boardings, diverts this traffic from the Central Subway. This diversion is particularly important for Arlington Station where long dwell time delays now occur due to high passenger volumes. These delays would be reduced with Systems 1 and 2, while the other systems produce high volumes comparable to current levels.

A more even distribution of station boardings along the Green Line for Systems 1 and 2 aids in reducing service delays. The concentration of passengers at certain stations has the effect of not only creating congestion at those stations but also transmitting these effects throughout the entire system.

Systems 1 and 2 also provide a "levelling" effect at Washington Station where the volume is reduced by 17% compared with the Base System. Reduction in passenger activity at Washington Station is especially important since this station and Park Street are the highest activity stations in the system and have two to three times greater activity than the next most active station. Park Station shows a 10%-20% increase in station boardings for Systems 1 and 2 compared with the other systems. This increase, which reflects diversion from Washington Station due to the Riverside-Orange transfer at Back Bay, can easily be absorbed by the newly expanded Park Station designed to accommodate the rerouted Riverside Line in Systems 1 and 2.

The passenger boardings at Bowdoin Station more than double with the Bowdoin-Park connector (Systems 1-3) indicating the improved service produced by the connector for Green Line riders destined for Beacon Hill area.

If the Huntington Line went to South Station, as a variation of Systems 3, Harrison Station on the rerouted Huntington Line (System 3) would attract only 1,700 boardings. These boardings appear to be diverted from South Cove Station on the Orange Line.

1990 DOWNTOWN SYSTEMS

STATION BOARDINGS (DAILY)

Downtown Station	SYSTEM 1	1(Modified)	2	3	Base
Aquarium	5,600	4,800	5,400	5,600	4,700
Arlington	10,100	11,100	8,900	17,900	15,400
Auditorium	6,300	6,200	4,200	5,100	5,100
Back Bay	24,400	23,900	23,000	17,000	20,100
Bowdoin	9,700	3,700	9,400	9,100	3,900
Boylston	2,300	2,500	2,200	1,100	4,900
Charles	6,600	7,700	6,700	6,900	7,900
Copley	6,100	6,400	6,000	12,300	10,500
Eliot	9,100	8,100	10,000	-	-
Essex	5,900	5,900	6,000	7,500	5,800
Government Center	7,100	7,100	7,400	4,800	8,800
Haymarket	8,700	9,900	8,700	8,500	9,900
Mass. Ave. (Orange)	5,800	6,000	5,000	5,500	6,900
North Station	8,200	8,900	8,300	8,000	8,600
Park	28,600	29,300	28,700	25,900	23,400
Prudential	1,100	1,100	5,100	2,600	1,100
South Cove	7,800	7,900	7,700	9,200	9,200
South Station	16,000	15,900	16,100	16,200	15,900
State	21,700	21,800	21,400	23,900	21,700
Symphony	300	300	1,100	600	200
Washington	37,900	41,100	37,900	41,600	45,600
Totals	229,300	229,600	229,200	229,300	229,600

Notes: System 1(Modified) is the same as System 1 without the subway connection between Park and Bowdoin.

Base System assumes the Green Line as it exists today.

The above figures were produced for comparison of the proposed systems. They do not include intra-downtown riders. Intra-downtown volumes are approximately 8% of the total downtown station boardings.

Table 9-2 illustrates the transfer volumes through each downtown transfer station for the four systems. Systems 1 and 2 produce the highest number of transfers downtown which are approximately 8% greater than the Base System, but 18% greater than System 3. Although System 3 produces the lowest number of transfers, it also produces the highest system travel times next to the Base System. Therefore, high transfer volumes in this comparison may be indicative of superior system performance when travel time is reduced. System performance should be judged by evaluating all travel time factors since transferring may be desirable when it reduces overall travel times.

The most important and dramatic changes in transfer volumes occur at Washington and Government Center Stations. The transfers at Washington are reduced 36% with Systems 1 and 2 (compared with the Base System), while the transfers at Park increase approximately 20%. As noted above in the discussion of boardings at these stations, a reduction in Washington Station activity is extremely important to relieve the tremendous pressure which now exists and which will increase in the future at Washington Station. The transfer volume increase at Park Station would be accommodated by the newly designed station in Systems 1 and 2. The transfers at State Station, which is also a high congestion station, would be reduced approximately 15% in Systems 1 and 2.

Government Center Station, which today provides the only direct transfer connection between the Blue and Green Lines, shows a drop in transfers from 22,300 for the Base System to 600-3,100 for the other systems due to the Park-Bowdoin connection. The connection is thus eliminating at least 20,000 transfers (two-way) per day. Approximately 30,000 transfers are eliminated system-wide with the Park-Bowdoin connection, since a substantial number of transfers are eliminated at Park and State in addition to Government Center Station due to the connection.

The transfers at Back Bay Station range between 47,000 to 49,000 for Systems 1 and 2 which derive the greatest use of this transfer facility between Green and Orange Lines. System 3 produces 10,000 transfers at Back Bay due to the lower volume and longer headways on the Huntington Avenue Line which provides the transfer between Orange and Green Lines. The Back Bay transfer becomes particularly beneficial for Southwest Corridor riders destined for Park Square, Beacon Hill, Government Center sections and thus diverts Orange Line riders from transferring at Washington Station.

1990 DOWNTOWN SYSTEMS

STATION TRANSFERS (DAILY)

Downtown Transfer Station	SYSTEM 1	1(Modified)	2	3*	Base
Arlington	500	700	-	-	700
Auditorium	7,900	6,500	-	-	2,200
Back Bay	48,900	45,700	46,500	10,000	-
Boylston	100	200	-	-	200
Copley	100	300	-	-	300
Government Center	2,000	23,800	3,100	600	22,300
Haymarket	-	-		-	7,800
North Station	13,000	13,000	12,700	1,300	-
Park Street	110,000	117,800	112,400	94,400	89,400
State	35,500	39,800	35,300	46,900	41,500
Washington	58,300	59,300	58,500	79,700	90,800
Totals	276,300	307,100	268,500	232,900 14,300* 247,200	255,200

*Note: In System 3, all Beacon and Commonwealth Line riders entering the downtown area must transfer at the points where these lines intercept the Riverside Line. This would add 14,300 to the total number of transfers for System 3. If, however, convertible cars were ultimately utilized as a variation of System 3, no extra transfers would be made at Kenmore.

The Huntington Avenue rerouting to South Station in a variation of System 3 permits a more direct access to the Back Bay for South Shore riders. Approximately 16,000 riders transfer at South Station between the Red and Huntington Lines. This benefit is offset however by the lack of transfer facility for Southwest Corridor trips which desire access to the Green Line as provided in Systems 1 and 2.

Table 9-3 presents a summary of the average passenger downtown trip time in the vehicle for each downtown system by line. System 2 provides the shortest total line time per trip followed by Systems 3, 1 and the Base network. This should not be used alone as an indicator of the best system performance since line time is only one element of time in the trip although it is the largest time component.

Table 9-4 shows the average downtown transfer time per trip for each system by line. System 3 provides the shortest transfer time followed by the Base network, then Systems 2 and 1. In this instance, the longer transfer times for Systems 1 and 2 indicate the increased opportunity for transferring afforded by these systems.

Table 9-5 shows the average walk time per trip downtown for each system by line. Systems 1 and 2 have the shortest walk times, followed by System 3 and the Base network. This is probably the best single indicator of system performance since it provides a measurement of how close the system is able to bring the passenger to his final destination, the ultimate goal of improving downtown system distribution.

Table 9-6 shows the total average time which is a sum of the line, transfer and walk times for each system by line. Systems 1 and 2 have the shortest total average time, followed by System 3 and the Base network. Thus, Systems 1 and 2 satisfy the criteria for minimizing walk time and total time for the total system. Systems 1 and 2 also provide the shortest walk time and total time for both the Green and Blue Lines.

The Base System, with present running times, exhibits a particularly high total time for the corridor-to-corridor trips, and especially for the trips from the Green Line to other corridors.

The average transfer and walk times for trips to downtown for each system by line are shown in Table 9-7. Systems 1 and 2

are superior to the other systems in terms of minimizing this time. The volume of trips to downtown for each system and the ridership differences for each system are also included in Table 9-7. The loss in ridership to downtown is approximately 2,000 trips for System 3 and the Base network compared with Systems 1 and 2 which act as the base for this comparison.

Table 9-8 shows the transfer and waiting times for trips through downtown for each system by line. Systems 1 and 2 provide shorter total system excess times than the other systems. This table also shows the trips through downtown for each system by line and the ridership differences for each system. The loss in ridership through downtown varies between 200 and 4,300 trips compared with System 2 which is the base for this comparison.

The ridership loss for each downtown system is shown in Table 9-9. The loss in revenue trips varies between 60 and 8,850, using System 2 as the base.

1990 DOWNTOWN SYSTEMS

TIME SUMMARY PROGRAM RESULTS

Line Time (Average Minutes Per Trip Downtown)

Transit Line	Trips To Downtown	SYSTEM 1	2	3	Base
Red (Ashmont)	52,300	7.66	7.66	7.65	7.87
Red (Harvard)	34,200	7.66	7.65	7.82	8.04
Orange (H-N)	39,600	8.94	8.96	8.96	8.94
Orange (S-W)	45,200	7.84	7.77	7.81	7.84
Blue (E. Boston)	19,600	8.18	8.17	8.39	8.85
Green	38,700	6.76	6.46	6.42	10.58
Total (Weighted)		7.81	7.76	7.79	8.62

1990 DOWNTOWN SYSTEMS

TIME SUMMARY PROGRAM RESULTS

Transfer Time (Average Minutes Per Trip Downtown)

Transit Line	Trips To Downtown	SYSTEM 1	2	3	Base
Red (Ashmont)	52,300	0.47	0.49	0.49	0.48
Red (Harvard)	34,200	0.50	0.45	0.49	0.48
Orange (H-N)	39,600	0.22	0.23	0.15	0.12
Orange (S-W)	45,200	0.28	0.26	0.09	0.08
Blue (E. Boston)	19,600	0.37	0.37	0.37	0.58
Green	38,700	0.21	0.15	0.08	0.11
Total (Weighted)		0.34	0.33	0.27	0.29

1990 DOWNTOWN SYSTEMS

TIME SUMMARY PROGRAM RESULTS

Walk Time (Average Minutes Per Trip Downtown)

Transit Line	Trips To Downtown	SYSTEM 1	2	3	Base
Red (Ashmont)	52,300	2.57	2.52	2.61	2.62
Red (Harvard)	34,200	2.55	2.50	2.61	2.74
Orange (H-N)	39,600	2.63	2.58	2.83	2.91
Orange (S-W)	45,200	2.78	2.93	3.35	3.22
Blue (E. Boston)	19,600	2.49	2.44	2.50	2.53
Green	38,700	2.91	3.02	3.50	3.61
Total (Weighted)		2.67	2.68	2.94	2.97

Table 9-6

1990 DOWNTOWN SYSTEMS

TIME SUMMARY PROGRAM RESULTS

Total Time (Average Minutes Per Trip Downtown)

Transit Line	Trips To Downtown	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM Base
Red (Ashmont)	52,300	10.71	10.67	10.75	10.97
Red (Harvard)	34,200	10.71	10.60	10.92	11.27
Orange (H-N)	39,600	11.79	11.77	11.93	11.97
Orange (S-W)	45,200	10.90	10.97	11.24	11.14
Blue (E. Boston)	19,600	11.04	10.99	11.26	11.96
Green	38,700	9.88	9.67	9.99	12.48
Total (Weighted)		10.82	10.77	11.00	11.88

Total Time (Minutes Per Trip Through Downtown)

Transit Line	Trips to Other Corridors*	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM Base
Red (Ashmont)	28,000	14.95	15.02	14.69	15.46
Red (Harvard)	19,200	14.42	14.42	14.94	15.67
Orange (H-N)	18,400	16.50	15.82	16.66	16.47
Orange (S-W)	18,700	15.21	15.29	17.54	20.16
Blue (E. Boston)	10,300	16.55	15.45	16.21	17.55
Green	20,700	14.24	14.00	15.23	20.82
Total (Weighted)		15.16	14.95	15.83	18.56

*Trips through downtown.

1990 DOWNTOWN SYSTEMS

TIME SUMMARY PROGRAM RESULTS

Transfer Plus Walk Times (Average Minutes Per Trip Downtown)

	SYSTEM			
Transit Line	1	2	3	Base
Red (Ashmont)	3.04	3.01	3.10	3.10
Red (Harvard)	3.05	2.95	3.10	3.22
Orange (H-N)	2.85	2.81	2.98	3.03
Orange (S-W)	3.06	3.19	3.44	3.30
Blue (E. Boston)	2.86	2.81	2.87	3.11
Green	3.12	3.17	3.58	3.72
Total (Weighted)	3.01	3.01	3.21	3.26

Trips to Downtown for Each System*

	SYSTEM			
Transit Line	1	2	3	Base
Red (Ashmont)	52,237	52,300	52,112	52,112
Red (Harvard)	34,105	34,200	34,057	33,944
Orange (H-N)	39,540	39,600	39,350	39,276
Orange (S-W)	45,200	44,980	44,554	44,793
Blue (E. Boston)	19,569	19,600	19,563	19,414
Green	38,700	38,598	37,765	37,480
Total	229,351	229,278	227,401	227,019
Differences:	+73	Base	-1,877	-2,259

*Developed by applying ridership time sensitivity factors to base volumes.

1990 DOWNTOWN SYSTEMS

Downtown Excess Times (Transfer Plus Waiting) For Corridor-To-Corridor Trips (Average Weighted Times)

Transit Line	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM Base
Red (Ashmont)	2.09	2.07	1.91	3.06
Red (Harvard)	2.27	2.24	2.14	3.03
Orange (H-N)	2.42	2.43	2.23	2.67
Orange (S-W)	2.86	2.73	3.15	3.90
Blue (E. Boston)	2.51	2.47	2.58	4.41
Green	2.60	2.53	3.00	3.73
Total (Weighted)	2.42	2.38	2.46	3.37

Trips Through Downtown for Each System

Transit Line	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM Base
Red (Ashmont)	27,820	27,840	28,000	26,855
Red (Harvard)	19,130	19,147	19,200	18,726
Orange (H-N)	18,270	18,263	18,400	18,099
Orange (S-W)	18,609	18,700	18,405	17,879
Blue (E. Boston)	10,287	10,300	10,264	9,667
Green	20,624	20,700	20,189	19,396
Total	114,740	114,950	114,458	110,622
Differences:	-210	Base	-492	-4,328

1990 DOWNTOWN SYSTEMS

Ridership Loss for Each System

	SYSTEM			
	1	2	3	Base
Trips to Downtown	+73	Base	-1,877	-2,259
Trips from Downtown	+73	Base	-1,877	-2,259
Trips through Downtown	-210	Base	-492	-4,328
Total	-64	Base	-4,246	-8,846

SECTION B

POLICY EVALUATION OF ROUTING ALTERNATIVES

This Section reviews the existing traffic data for the three Riverside alignments described in the previous section, and the systems of which they form a part. Each of the total systems tested included a Park-Bowdoin connection, with variations in access to Park Street. The specific segments given intensive analysis are therefore (1) Park Street to Bowdoin; (2) Brookline Village to Park Street via a new Huntington tunnel; (3) Fenway Park to Park Street via the Boston and Albany right-of-way; and (4) Fenway Park to Park Street via the Central Subway.

THE BLUE-GREEN CONNECTION - PARK STREET TO BOWDOIN

The effect of the Blue-Green connection has been measured in terms of travel time changes for trips made on each rapid transit line to and through the downtown area. The analysis has shown that approximately 1,000 out of 230,000 trips to downtown in 1990 would be lost without the connection, and approximately 2,000 out of 115,000 trips through downtown would be lost without the connection.

Based on the above 1990 estimates, the rapid transit revenue producing potential of the Blue-Green connection is $300,000 annually, assuming a $.25 fare per trip; however, with the zone fare system used for the 1990 traffic projections the average fare would be higher than $.25 and the revenue potential would then be somewhere between $300,000 to $600,000 annually. A more precise estimate of the potential rapid transit revenue would require calculation of the average fare determined from the estimated traffic volumes boarding at each station and the fares to downtown from each station. This calculation was not made.

The rapid transit lines which would be affected by the Blue-Green connection in terms of trips through downtown (i.e., corridor-to-corridor trips) are shown in the following table.

Corridor From	Corridor To	1990 Forecast Trips	Est. Lost Trips Through Downtown W/O Blue-Green Connection	(% Lost)*
Harvard	E. Boston	3,939	340	(8.7%)
E. Boston	Harvard	2,461	242	(9.8%)
E. Boston	Riverside	1,924	310	(16.2%)
Riverside	E. Boston	3,578	960	(26.8%)
Total			1,852	

*The different percentages are due to both variation in trip times and corridor sensitivities to travel time changes.

The following table indicates the effect of the Blue-Green connection on trips to downtown (i.e., corridor to downtown).

Corridor	1990 Forecast Trips To Downtown	Est. Lost Trips To Downtown W/O Blue-Green Connection	(% Lost)
South Shore	52,323	-	-
Haymarket	39,648	-	-
Harvard	34,233	95	(0.2%)
Beacon-Commonwealth	5,851	15	(0.2%)
East Boston	19,628	155	(0.7%)
Huntington	1,932	25	(1.2%)
Southwest	45,236	-	-
Riverside	31,008	730	(2.3%)
Total		1,020	

Comparison of the two tables given above shows the relative impact of connecting the Blue and Green Lines is considerably greater for corridor-to-corridor trips than for corridor-to-downtown trips. However, since the absolute volume of corridor-to-corridor trips is forecast to be 115,000, while the corridor-to-downtown trips is 230,000, the connection does not produce a dramatic impact in terms of total traffic affected. The total

estimated lost revenue rides are approximately 4,000 out of 575,000 /i.e., (230,000 x 2) + 115,000/ or only 0.7%. Based on the 1969 rapid transit revenue of approximately $32 million (rapid transit and surface streetcar) the 0.7% would represent nearly $224,000 lost annual revenue in terms of the 1969 level of rapid transit ridership volume. The $32 million in revenue includes revenue from local riding which does not enter the downtown area and would be relatively unaffected by the downtown system changes; thus, the $224,000 lost revenue is somewhat inflated due to including this local riding in the above calculations.

It may be concluded from the above discussion that if the Riverside Line is removed from the Central Subway and follows the alignment described and terminates at Park Street Station, the estimated passenger revenue gained from connecting this alignment to the Blue Line in terms of 1990 ridership estimates is between $300,000 and $600,000 annually; and in terms of current ridership levels the estimated revenue gain is approximately $200,000 annually.

Based on a capital cost of at least $12.25 million to make the tunnel connection between Park Street and Bowdoin Stations, the $200,000 annual revenue gain from the connection appears to be economically infeasible (at an annual cost of revenue bonds amortized over 40 years at 5% interest charges compounded annually CRF=0.0583, the $12.25 million investment would cost $715,000 per year). Assuming the upper limit of $600,000 annually from the connection in terms of 1990 volumes, the connection is still economically infeasible.

The above analysis is extremely limited since there are indirect economic benefits which could result from the connection but which have not been considered in the above.

The results of the analysis of a Bowdoin to Park Street connection on travel times indicates the Riverside Line riders would experience the following reductions in travel time downtown with the connection.

80% transfer time reduction
11% walk time reduction
1% line time reduction
5% total time reduction

The East Boston Blue Line riders would experience the following reductions in travel time downtown with the connection.

60% transfer time reduction
1% walk time reduction
2% line time reduction
4% total time reduction

Travel times on the remaining rapid transit lines generally decreased by less than 1%.

The total downtown travel time savings with the connection is approximately 465 hours per day (one-way) out of approximately 41,500 total passenger hours (one-way). The 465 hours in time savings represents only 1% of the total downtown travel time, and in terms of the projected 1990 value of passenger travel time of $4.42 per passenger hour, the travel time savings using 1990 demand volumes resulting from the Blue-Green connection represents $680,000 annually.

Connecting the Riverside Line to the Blue Line between Park and Bowdoin Stations has some effect on the downtown station activities, the most notable changes being the following (Table 9-1):

Bowdoin Station daily boardings increase 162% from 3,700 to 9,700, and Aquarium and Eliot (Park Square) increase by 17% and 12%, respectively, while Arlington, Charles, Haymarket and Washington each decrease by amounts from 8% to 14%.

In terms of station transfers (two-way), the connection produces the following notable changes (Table 9-2):

Back Bay transfers increase 7% from 45,700 to 48,900.
Government Center transfers decrease dramatically from 23,800 to 2,000.
Park Street transfers decrease from 117,800 to 110,000.
State Station transfers decrease from 39,800 to 35,500.
System wide, the transfers downtown decrease 10% from 307,100 to 276,300.

In evaluating the Blue-Green connection using the detailed assignment results by lines, consideration has been given to the distribution of trips downtown for the East Boston Blue Line and the Riverside Line. The connection does not show

particular promise for the Blue Line trips downtown since approximately 22% of the Blue Line riders alight from Green Line stations along the rerouted Riverside Line, while nearly 50% alight from downtown stations along the existing Blue Line. Nearly 30% of the Blue Line riders alight from Orange Line stations, while less than 5% use the Red Line stations (not including Park Street and Washington Street Stations). The most notable change in downtown station usage by Blue Line riders is the shift of approximately 1,200 trips from Eliot Station to Arlington Station when the connection is eliminated.

The Riverside Line trip distribution downtown also indicates somewhat limited value in connecting this line to the Blue Line. Approximately 60% of the Riverside Line trips alight at stations along the Riverside Line up to and including ParkStreet Station, while approximately 20% of the Riverside Line trips use the Blue Line stations (Aquarium, Bowdoin, State and Government Center) when the connection is made. The most notable change in downtown station usage by Riverside Line riders is a shift of approximately 2,000 riders from Bowdoin to Park Street Station when the connection is eliminated. Use of the Blue Line stations by Riverside Line riders changes from approximately 6,000 (20%) to 1,500 (5%) one-way trips with the connection eliminated, indicating that 15% (rather than 20%) of the Riverside Line riders to downtown find the connection convenient.

The detailed assignment results, which were used for the above discussion, are available for inspection but were not attached to this report because of their bulk.

The Park-Bowdoin connector was chosen as part of a continuing study to determine the best possible comprehensive program to improve access to critical downtown high-activity areas. The alignment choice was partially made on the assumption that State Station could become a logical entrance point to the poorly-served financial district for Western Corridor patrons.

The reader is referred to Volume II for a full description of the process of selection of the Park-Bowdoin connection for engineering analysis. That volume explains the complexity of direct routings, in terms of establishing a feasible routing under existing structures and utilities. Our concern in this chapter is primarily with the nature of service created by each alternative.

A direct connection between Park (Green) and State (Blue) Stations (if one were physically possible), has the undesirable effect of seriously worsening the transportation of those who need access to Government Center destinations. Government Center and Bowdoin Stations would then be on a short branch. The Riverside patrons would receive better access to the State Street area, but State Street would not become a major financial district gateway. The connection would increase State Station patronage from Riverside by about 800 passengers, few of whom have destinations in the poorly served areas of the financial district. Principal access to these areas continues to be by foot from Park Street.

Operating Costs

An effort was made to determine the probable effect on operating costs of the proposed connection between Park Street and Bowdoin. The results of these calculations are shown in Tables 9-10, 9-11 and 9-12, which are based on System 1, 2 and 3 configurations, respectively.

In any such analysis, the assumed headways will have a profound effect on the total operating cost. The traffic forecasts for the various 1990 systems made by Peat, Marwick, Mitchell & Co. assumed the best possible headways on all lines (1-1/2 minutes in the case of the downtown portions). The results showed that in most cases the forecasted traffic could be accommodated using headways longer than those assumed. Longer headways would in turn tend to reduce the traffic demand, but the effect would not be great enough to be worth the costly process of "iteration" that would be necessary to arrive at the optimum headways.

For the purpose of estimating operating costs, headways were selected that would be adequate for handling the 1990 forecasted traffic, with train lengths as per present practice.

For System 1 (Table 9-10), it appears that operating costs would be about \$4.9 million higher with the connection than without; for System 2 (Table 9-11), the costs would be about \$2.9 million higher, and for System 3 (Table 9-12), they would be about \$2.5 million higher. The reason for these surprisingly large differences in operating costs is simply that without the through route, the headways on each leg can be better adjusted to accommodate the demand, so that neither leg is over-serviced. On the

other hand, the existence of the through route encourages more traffic and tends to balance the demand on the individual legs. The through-routing of two separate lines produces no particular efficiencies in the utilization of manpower. The headways are the all-important factor. On the face of it, the large increases in operating costs resulting from a tunnel connection of only 1,200 feet would seem unjustified, yet we must bear in mind that other factors would influence a decision. In short, how well would the public be served by this connection?

In this instance, projected operating costs alone do not provide a very good tool for decision-making.

Table 9-10

System 1

Western and Northeast Corridors Connected via B&A Right-Of-Way		Peak-Hour Headway (Minutes)	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Routes (With Connector):					
Riverside to Wonderland via B&A Right-Of-Way	(High Level)	2.5	$15,994,148	7,983,104	136
Cleveland Circle to No. Sta.	(Low Level)	5.0	2,841,729	1,088,660	51
Boston College to No. Sta.	(Low Level)	4.0	4,201,278	1,609,500	69
Huntington Ave.(New Loop) to No. Sta.	(Low Level)	3.0	1,760,752	674,540	46
Arborway to Huntington Ave.(New Loop)	(Bus)	2.0	539,697	349,160	20
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	9
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,600	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,590	9
TOTAL COST:			$27,162,441		

Western Corridor via B&A Right-Of-Way Not Connected to Northeast Corridor					
Routes (Without Connector):					
Riverside to Park St. via B&A Right-Of-Way	(High Level)	5.0	$ 5,558,680	2,690,943	60
Wonderland to Bowdoin) Orient Heights to Bowdoin)	(High Level)	2.5	5,585,820	2,704,081	56
Cleveland Circle to No. Sta.	(Low Level)	5.0	2,841,729	1,088,660	51
Boston College to No. Sta.	(Low Level)	4.0	4,201,278	1,609,500	69
Huntington Ave.(New Loop) to No. Sta.	(Low Level)	3.0	1,760,752	674,540	46
Arborway to Huntington Ave.(New Loop)	(Bus)	2.0	539,697	349,160	20
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	9
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,600	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,590	9
TOTAL COST:			$22,312,793		

Table 9-11

Western Corridor Connected With Northeast Corridor via Huntington Avenue		Peak-Hour Headway (Minutes)	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Routes (With Connector):					
Riverside to Wonderland) via Huntington Riverside to Orient Hts.) Avenue	(High Level)	2.5	$17,310,004	8,685,401	148
Cleveland Circle to North Station	(Low Level)	5.0	2,841,729	1,088,660	51
Boston College to North Station	(Low Level)	4.0	4,201,278	1,607,500	69
Arborway to Copley Square	(Bus)	2.0	975,398	631,040	30
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	9
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,600	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,570	9
Brookline Village to Park St.	(Low Level)	10.0	289,825	179,982	18
TOTAL COST:			$27,443,071		
Western Corridor via Huntington Ave. Not Connected with Northeast Corridor					
Routes (Without Connector):					
Riverside to Park St. via Huntington Ave.	(High Level)	3.0	$ 8,944,499	4,430,163	80
Wonderland to Bowdoin) Orient Hts. to Bowdoin)	(High Level)	2.5	5,459,539	2,704,081	56
Cleveland Circle to North Station	(Low Level)	5.0	2,841,729	1,088,660	51
Boston College to North Station	(Low Level)	4.0	4,201,278	1,609,500	69
Arborway to Copley Square	(Bus)	2.0	975,398	631,040	30
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	7
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,601	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,590	9
Brookline Village to Park St.	(Low Level)	10.0	289,825	179,982	18
TOTAL COST:			$24,537,105		

Table 9-12

Western Corridor via Boylston St. Subway Connected with Northeast Corridor		Peak-Hour Headway (Minutes)	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Routes (With Connector):					
Riverside to Wonderland) via Boylston Reservoir to Orient Hts.) St. Subway	(High Level)	2.0	$17,436,990	8,753,070	144
Huntington Ave.(New Loop) to No. Sta.	(Low Level)	3.0	1,760,752	674,540	46
Cleveland Circle to Beacon Junction	(Low Level)	5.0	1,370,146	524,900	27
Boston College to Kenmore	(Low Level)	4.0	2,622,960	1,004,850	51
Arborway to Huntington Ave.(New Loop)	(Bus)	2.0	539,697	349,160	20
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	9
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,601	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,590	9
TOTAL COST:			$25,555,382		

Western Corridor via Boylston St. Subway Not Connected with Northeast Corridor		Peak-Hour Headway (Minutes)	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Routes (Without Connector):					
Riverside to Park St. via Boylston St. Subway	(High Level)	2.0	$ 9,420,773	4,677,411	84
Wonderland to Bowdoin) Orient Hts. to Bowdoin)	(Low Level)	2.5	5,446,290	2,704,081	56
Huntington Ave.(New Loop) to No. Sta.	(Low Level)	3.0	1,760,752	674,540	46
Cleveland Circle to Beacon Junction	(Low Level)	5.0	1,370,146	524,900	27
Boston College to Kenmore	(Low Level)	4.0	2,622,960	1,004,850	51
Arborway to Huntington Ave.(New Loop)	(Bus)	2.0	539,697	349,160	20
Clarendon Hill to Community College via Somerville Ave.	(Bus)	7.5	432,564	279,850	9
Clarendon Hill to Community College via Highland Ave.	(Bus)	5.0	466,183	301,601	16
Arlington Center to Community College via Medford Hillside	(Bus)	6.0	670,138	433,550	13
Harvard Square to Community College via Cambridge St.	(Bus)	7.0	255,952	165,590	9
TOTAL COST:			$22,985,455		

KEY ASPECTS OF THE DOWNTOWN SYSTEMS

The Penn Central (B&A) Right-Of-Way
(System 1, and System 1 Modified)

The above analysis indicates that connecting the Blue and Green Lines between Park Street and Bowdoin is not justified on economic grounds. The analysis also demonstrates the superiority of Systems 1 and 2 over System 3 and the Base System. The question arises as to the validity of this conclusion when the Bowdoin-Park connection is eliminated from Systems 1, 2 and 3, i.e., is System 1 still superior to Systems 2 and 3 when these systems are modified by eliminating the new connection? Retesting all of these systems, modified without the connection, using the downtown assignment model would be expensive and time consuming. It is assumed that since System 1 Modified (i.e., without the connection) is considerably superior to the Base System ("do nothing" system), as shown from the following discussion, then the relative order of preference among Systems 1 through 3 is unchanged when the connection is eliminated from these systems.

The effect of removal of the Riverside Line from the Central Subway was evaluated by comparing two alternative systems using a common 1990 volume trip table. The Base alternative, 1990 System includes the existing Green Line alignments and the new Orange Line alignment which describes the Downtown system configuration which is anticipated by 1975. The comparative alternative, 1990 System 1 Modified, assumes the Riverside Line is rerouted out of the Central Subway and follows the B&A right-of-way from Fenway Park to Back Bay and thence via new subway to a terminal at Park Street Station.

Removing the Riverside Line from the Central Subway first affects Riverside Line travelers entering into and passing through the Downtown area. The new alignment also affects travelers from other transit lines who now use the affected portion of the Green Line. Approximately 75% of the trips to Downtown via the Riverside Line alight at stations along the Green Line up to and including Park Street Station. If the Riverside Line were removed from the Central Subway as noted above and terminated at Park Street, approximately 20% of the Riverside Line riders would be affected by this termination and would be required to make an extra transfer downtown to reach their final destinations. The remaining 5% of the Riverside Line riders would be unaffected by the termination at Park Street and would continue to transfer at

Park Street Station to reach destinations along the Red Line. The new Riverside alignment Downtown provides improved access to downtown destinations for the Riverside Line riders since the total travel time downtown is reduced by 31% over the existing Riverside alignment. Included in the 31% reduced downtown travel time is a 13% reduction in walk time from final destination station to destination zone, a 40% reduction in downtown line time, but a 245% increase in downtown transfer time which is mainly due to the substantial transfer volume between the Riverside and Orange Lines at Back Bay Station. This high percentage increase in transfer time does not necessarily indicate a reduction in service quality but rather reflects transfer increases resulting from opting to the shorter travel paths on the Downtown system. This percentage increase in transfer time is also partially the result of terminating the Riverside Line at Park Street. Any analysis of removing the Riverside Line from the Central Subway is affected by both the alignment and terminal location. Thus, the above discussion should not be construed to mean that it is necessarily beneficial to Riverside Line riders to remove the Riverside Line from the Central Subway unless one strictly understands that the above benefits in travel time apply to the specific alignment under consideration. This particular alignment was selected for study contingent on connecting the Riverside Line to the Blue Line between Park Street and Bowdoin Stations. Analyses indicate little economic justification for this new connection, and it would therefore appear invalid to consider converting the Riverside Line to high-platform service via the B&A right-of-way and terminating this service at Park Street. However, as noted above, overall service for the Riverside Line riders is improved by this new alignment even with the constraint of terminating the Riverside Line at Park Street Station. Therefore, even though the original intention of this alignment may not now be valid, there would be definite travel time benefits from this alignment.

Considering the total downtown rapid transit system, the described Riverside Line realignment would produce an overall 8% improvement in total downtown travel time, which is composed of an overall 4% improvement in Line time, 8% improvement in Walk time, but a 32% increase in Transfer time downtown. This transfer time increase again reflects the improved access between the Green and Orange Lines at Back Bay Station and indicates an increased level of service.

Comparison of the two Riverside Line alternatives indicated above were made to determine changes which would be expected in the Downtown Station activities. The new Riverside alignment would generate approximately 46,000 transfers at Back Bay Station (common to the Riverside and Orange Lines), increase the transfers at Park Street Station from approximately 90,000 to 118,000, and reduce the transfers at Washington Station from approximately 90,000 to 60,000.

The station boardings at Arlington Station would decrease from approximately 15,000 to 11,000; Boylston Station boardings would decrease from approximately 5,000 to 2,500; Copley Station boardings would decrease from approximately 10,000 to 6,500, and Washington Station boardings would decrease from approximately 45,000 to 41,000, while Park Street boardings would increase from approximately 24,000 to 30,000. The new Eliot Station (at Park Square) on the rerouted Riverside Line would generate approximately 8,000 daily boardings. The Back Bay Station boardings would increase from approximately 20,000 to 24,000.

Some events have occurred since the inception of the CASS Project which have a bearing on the probable availability of the Penn Central (B&A) right-of-way between Fenway, Park and South Station for use in a System 1 solution. This right-of-way is owned by the Massachusetts Turnpike Authority, but is available to the Penn Central in perpetuity as long as it is used for railroad purposes. In recent years, use of this trackage for both freight and passenger service has dwindled to the point of near disappearance. What little passenger service remains is being furnished under protest and could cease in the near future. This would be a logical corridor for fast, frequent transit service, and our early conversations with both the Railroad and the Turnpike Authority were encouraging as to the future availability of this right-of-way.

This Authority, however, could not be a party to the discontinuance of any existing passenger service unless it were in a position to offer an alternative service as good or better. The problems of providing good alternative transit service by rail or road, west of Fenway Park in the B&A service area, are complex (see Chapters 4 and 6 of Volume II).

Since the Penn Central's recent agreement to sell its yard property in the South Bay area to the MBTA for a yard and maintenance shop complex, it will now be necessary for them to preserve an access route between the South Bay-South Station area

and their maintenance facilities at Beacon Park, just west of Fenway Park, for the movement of locomotives.

Another factor to be considered is the recent revival of interest in high-speed inter-city railroad passenger service. Proposals have been advanced whereby, with Government sponsorship, a high-speed rail service between Boston, Worcester, Springfield and New York might be set up. Such a service would necessarily use this corridor, and its availability should be preserved in the public interest, at least for the next few years.

The above considerations mean that the Penn Central will have to maintain at least one track between Fenway Park and South Station for passenger service and movements to and from Beacon Park yard. Thus, only one of the two tracks in this area could be made available to the MBTA under present conditions.

Single track, two-direction operation for rapid transit service for this relatively short distance, say from Fenway Park to Columbus Avenue (6,150 feet), is perhaps feasible but certainly not desirable. It might be possible to construct a third track eastward from Fenway Park to near Massachusetts Avenue, about 2,100 feet, thereby shortening the length of single-track operation to about 4,000 feet.

Cost estimates for this single-track alternative have not been prepared since it does not seem sufficiently attractive at this time. The short headways required for a high-density operation could not be maintained, especially with one or two station stops in the single track section.

The Engineering Consultant, DeLeuw, Cather & Company, has estimated that the construction cost of System 1 in 1970 dollars would be $137 million. The detailed breakdown of these costs by geographical segments can be found in Volume II. They do not include such things as right-of-way costs, relocation of privately-owned utilities, or rolling stock.

Although System 1 and System 1 Modified do have clear benefits, as shown in the previous discussion, the high capital cost and the complications of obtaining the B&A right-of-way militate against recommending construction of any portion at this time.

The Brookline Village-Huntington Avenue
Subway Routing (System 2)

Since System 1 cannot and should not be implemented at this time, we turn to System 2, as it does not require use of the B&A

right-of-way, and discussion in Section A of this chapter has shown that its overall benefits are very similar to System 1.

The Engineering Consultant has estimated the total construction cost of System 2 at $198 million. See Volume II for details.

CASS socio-economic research has established that the Brigham Circle area is really an extended portion of downtown rather than corridor in nature. What is needed is a service that necessarily sacrifices line speed in order to provide short station spacing and high levels of distribution. This end would not be provided by the construction of a subway under Huntington Avenue. The cost would render a certain level of benefit to the Riverside riders as they would gain an exclusive right-of-way to downtown; but the patrons from all other corridors desiring access to the Fenway would not benefit. The other corridor passenger needs are for the type of coverage-intensive distribution facilities which exist today.

The long-term solution to solving the Copley Junction problem and serving the needs of Huntington Line riders may well come in an inter-modal solution to several Central Area service needs. The problem is not simple, and the CASS study does not pretend to have done long-term planning on this scale. What has emerged, as the reader will note in Chapter 7, is a concept that the Huntington Line may be converted using a new technology within the planning period. Thus, it is possible that a low cost solution will be found for downtown routing of the Huntington Line.

A solution concerning the Broadway portal of the Tremont Street Subway cannot be determined until more information on South End and Fenway transit needs has been developed. It is unwise today to recommend a subway from Huntington to Broadway portal under the Turnpike at a total cost of over $20 million for a line whose volumes may fall under 10,000 passengers per day, depending on where it is truncated.

Construction of the new Orange Line Southwest Extension will undoubtedly have a profound effect on Huntington Avenue Line ridership, since it will be providing an essentially parallel service to Northeastern University from downtown. Any major capital investments for the Huntington Avenue Line should be postponed until the Southwest Extension is built and its actual impact can be measured, or a final decision is made not to build it.

The traffic forecasts indicate a drastic drop in Huntington Avenue Line ridership, to the point where this demand could perhaps be handled by surface buses. In this event, the foregoing argument against extending the Huntington subway for use by the Riverside Line would lose much of its strength.

The information available at this time strongly supports the position that Huntington Avenue service should stay in Copley Junction until such a time as a low capital cost solution is found. There is strong evidence that a new tunnel connection would not be the best allocation of resources. The strongest and most important conclusion, however, is the inadvisability of making a Riverside tunnel investment through the Fenway area whose present modal needs require another form of service.

The benefits of a private Riverside alignment have not proven sufficient to justify construction costs when analyzed strictly in terms of benefits created for corridor riders, and (in the case of Huntington) the areas through which it must pass. However, with sizable growth in the patronage of the system as a whole, it is possible that a new downtown east-west alignment might be needed to effectively handle downtown movements.

The downtown distribution model was created in order to provide this information. Its output includes the line volume for each link in the downtown sytem so that possible overflows of capacity can be determined. Tables 9-13, 9-14 and 9-15 give graphic displays of these line volume forecasts.

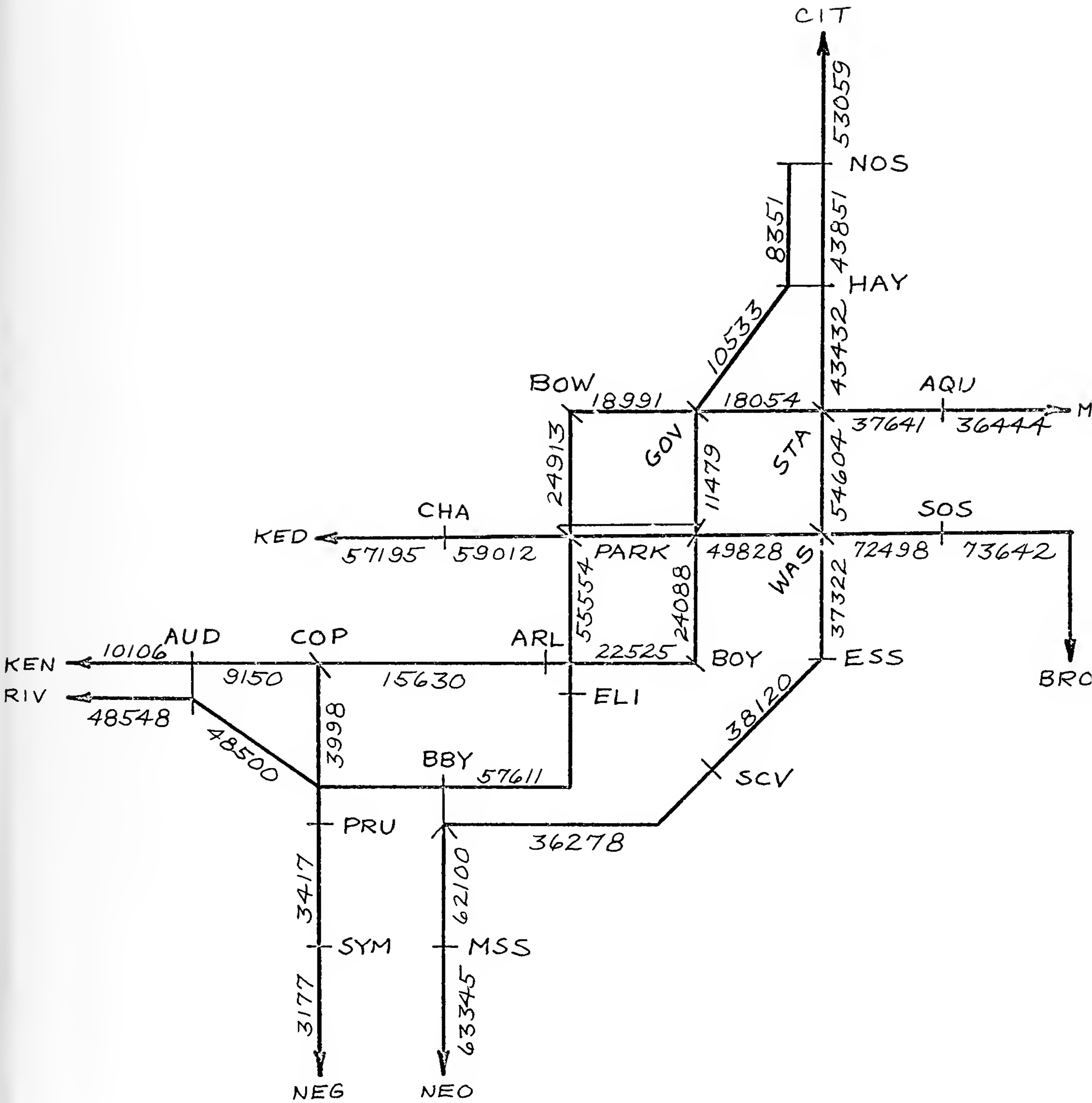
DO THE FORECAST VOLUMES JUSTIFY A NEW ALIGNMENT?

The 1990 volumes of traffic forecast for each link do not justify a new Back Bay distribution tunnel to downtown on the basis of capacity limitations. The heaviest link in the system today is between Park and Arlington Streets, specifically on the two-track segment between Boylston and Arlington. The highest figure determined for this link is approximately 59,000 one-way passengers per day in 1964.

The highest 1990 forecast determined for this link is only 64,000, which resulted from a system which routed Riverside but not Huntington Avenue through the Central Subway (System 3). The distribution function of the Central Subway will not be replaced by the new Orange Line, but the construction of the Orange Line will significantly lighten the distributional burden otherwise placed on the Central Subway. If the line

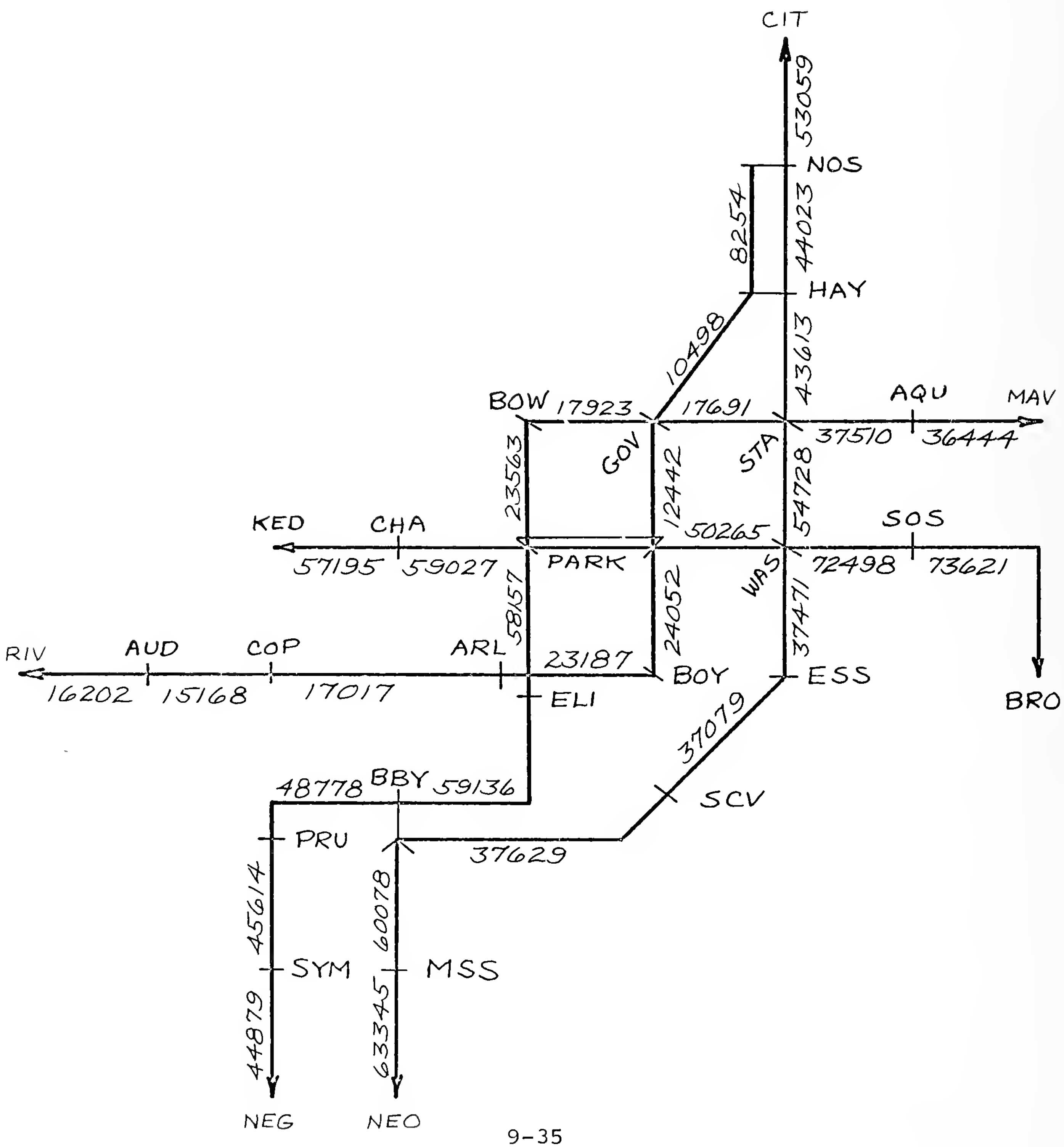
1990 DOWNTOWN SYSTEM 1

Projected Traffic
24-Hour One-Way Volumes



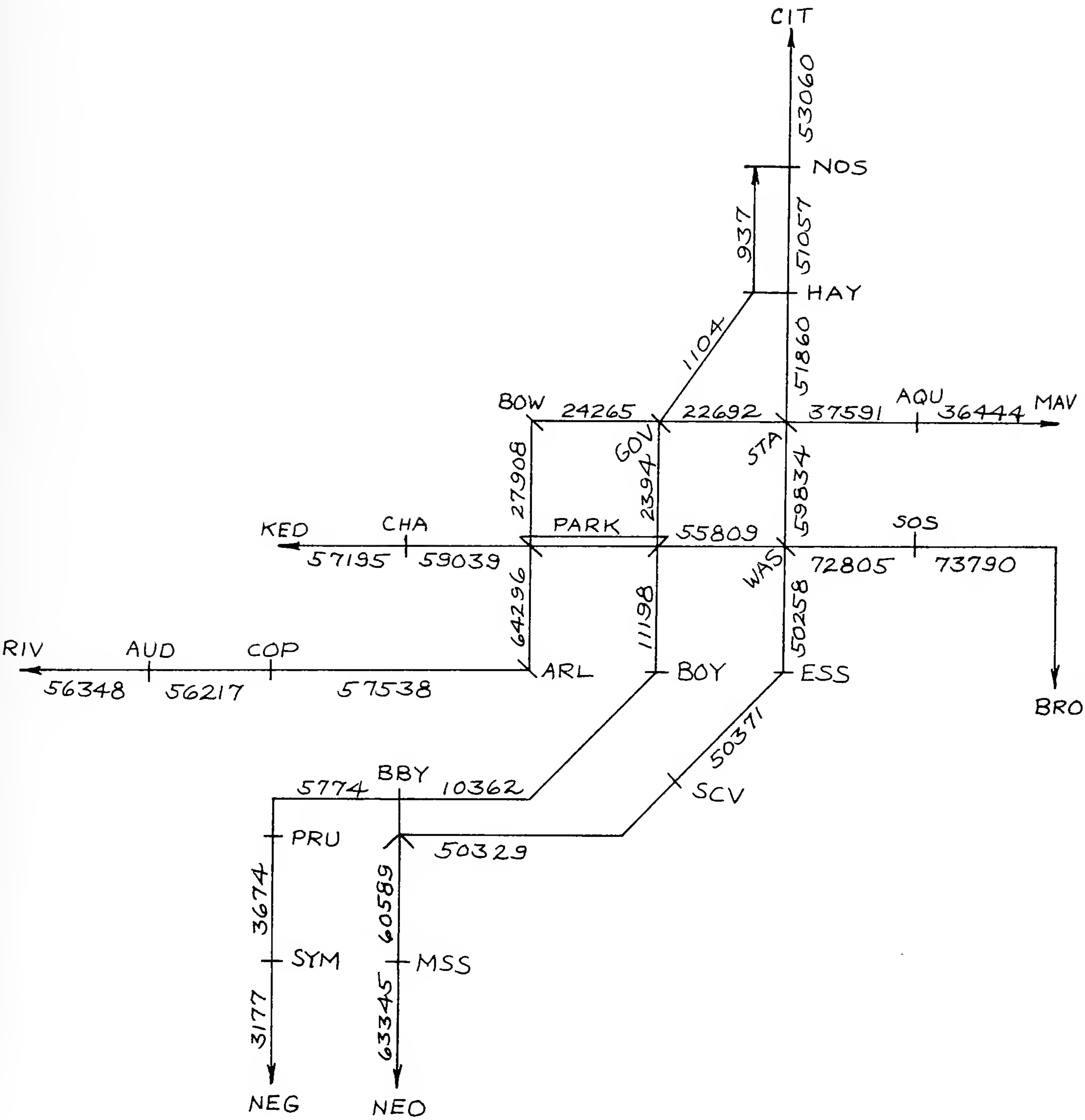
1990 DOWNTOWN SYSTEM 2

Projected Traffic
24-Hour One-Way Volumes



1990 DOWNTOWN SYSTEM 3

Projected Traffic
24-Hour One-Way Volumes



volume through Arlington Station revealed an inability on the part of the Central Subway to handle the volumes forecast, a strong argument could be made to create a new Western Corridor tunnel. However, the 1990 volume link is not the heaviest in the system. By way of comparison, it is about the same as the Orange Line 1990 volume through Massachusetts Station, and nearly 10,000 less than the Red Line 1990 volume through South Station. What are revealed are not volumes that demand the construction of a new facility, but rather volumes that demand a high level of performance from an existing facility. These are typical high-platform rapid transit volumes when compared with the Red and Orange Lines. It is doubtful if a sufficiently high level of performance could be achieved without conversion of the Central Subway to high platforms, as in System 3. On the other hand, if conversion is not made, these predicted line volumes will probably never be realized because the demand will be commensurate with the lower performance level inherent in low-platform operation.

The Engineering Consultant has estimated that conversion of the Central Subway to high platforms could cost as much as $180 million. Chapters 5 and 7 have already pointed out the damage that could result from disruption of existing service patterns, and the importance of preserving the "one-trip" surface-subway concept in the Green Line service area. The cost of System 3 could be somewhat reduced by means of simplified surface-to-subway transfer facilities and not connecting to the Blue Line, but only at the further sacrifice of riderhsip. Systems 1 and 2 do have some definite advantages over System 3 as discussed earlier and, in the long run, the adoption of a new Riverside alignment might prove to be the best solution to a potential capacity problem.

In all of the system solutions studied, and even the Base System, the completion of the new Orange Line Southwest Extension was assumed. Completion of this extension had been a foregone conclusion up until very recently. Now construction of this extension has been held up because of the controversy over the extension of Interstate Route 95, and its future is uncertain. We still believe it will be completed, but if it should not be, the traffic demands on the downtown portion of the Green Line, and especially the Huntington Avenue portion, would be considerably greater than any shown on the tables of this chapter.

As mentioned in Chapter 8, the Authority is now investigating several types of European cars, which include a type which has movable steps, adaptable to either low or high-level platforms. With this type of car, a much less costly version of System 3 would become possible. The need for transfer facilities would be eliminated, and stations could be converted to high platforms on an individual basis, as required by increased traffic.

SECTION C

CONCLUSIONS AND THE RECOMMENDED PLANNING PROGRAM FOR DOWNTOWN SYSTEM IMPROVEMENTS

Transit ridership estimates based on the results of corridor studies indicate there will be significant increases in corridor-to-downtown and corridor-to-corridor transit trips. These ridership increases will have appreciable impacts on the downtown system which will compound the congestion problems experienced in the Central Subway today. Downtown system activity levels in 1990 (boardings, alightments, transfers) are expected to exceed 1963 levels by 60%. Corridor-to-corridor transit trips in 1990 are estimated to exceed 1963 volumes by nearly 85%. Improvements in the downtown system must be accomplished to adequately accommodate this projected growth.

Systems 1 and 2 provide superior service for trips, both to and through downtown, primarily due to the transfer connection between Orange and Green Lines at Back Bay Station. This transfer facility provides a more beneficial function than the Blue-Green Line connection between Park and Bowdoin Stations.

System 3, which involves converting the Central Subway to high-platform operation, is inferior to Systems 1 and 2 for two major reasons:

1. Surface Green Line riders (Beacon, Commonwealth Lines) are forced to transfer to the Riverside Line before entering the downtown area. This transfer results in a substantial inconvenience and ridership loss.

2. The substantial benefits of connecting a high-volume Green Line (Riverside Line) to the Orange Line at Back Bay Station are not realized (System 3, the low-volume

Huntington Line, connects to the Orange Line at Back Bay which proves rather ineffective due to the large volume diverted from the Huntington Line to Orange Line west of Back Bay where the lines serve a common market area).

The Base System is considerably inferior to Systems 1, 2 or 3, primarily due to the absence of a transfer facility at Back Bay between Green and Orange Lines, in addition to the absence of a through connection between Blue and Green Lines and the longer running times on the Green Line.

The measured benefits derived from connecting the Blue and Green Lines are not sufficient to justify either the operating or capital costs involved with this connection.

The slight differences in benefits between Systems 1 and 2 do not provide justification for the high costs involved in System 2 (new subway from Brookline Village to Brigham Circle and under Huntington Avenue to Northeastern).

System 1 Modified (without the Bowdoin-Park connection) provides the best service quality at the least cost of the major systems considered.

Unhappily, all of the systems studied have major drawbacks. Under present conditions, System 1, or System 1 Modified, could not be adopted anyhow because of the foreseeable needs of the Penn Central for the B&A right-of-way.

The capital needs of the Authority for construction of already-committed projects are so great that it is doubtful if sufficient funds could be obtained to implement any of the three major system solutions within the next few years.

The CASS study has revealed a considerable potential of the Central Subway to cope with higher volumes than it is carrying today, and we recommend that no conversion be made to high platforms and that the Authority should plan for the Riverside Line to remain in the Central Subway alignment for the next decade.

Briefly reviewing the data presented in this chapter, the traffic analysis of three hypothetical 1990 systems revealed that Systems 1 and 2 were superior to System 3. Analysis of this information showed that this superiority stemmed primarily from the improved walk time capabilities. This network comparison demonstrated

again the need for improved access patterns out from Back Bay Station. Section B examined the probability of implementation and concluded that both the Boston and Albany alignment and the Huntington Avenue alignment should be deferred at this time.

With the resolution of the Riverside alignment question itself, there are three major areas in which the CASS study must provide direction for continuing planning and operational efforts of the Authority. These are (1) the future operation of the Central Subay, (2) the resolution of the Huntington-Copley Junction problem, and (3) implications for further research. This concluding section proposes a staged incremental decision-making process for this effort.

The downtown planning study of the Central Area Systems Study does not conclude with the recommendation of any one particular 1990 system. Without negating the value of conducting extensive traffic research on complete 1990 systems, it must be noted that what is needed is a decision-making process that will make use of all available planning information between the present and the target date of 1990. The CASS study has been designed to give strong emphasis to those system investments which bring marked levels of system improvements without closing out options for action at a later date.

The conclusion of the long-term planning study that the Riverside Line should stay in the Central Subway for the next decade strongly reinforces the validity of the Immediate Action Program, and its important investments in the existing facility. All of these recommendations, described in the following chapter, meet the criterion of leaving future investment options sufficiently open and unconstrained. The extensive engineering and traffic research of the CASS has revealed the levels of service that are possible under varying conditions of investment. The CASS study research has pointed out that by far the greatest incremental benefits per dollar invested will accrue from improvements in the existing facility. The five-minute running time established in System 3, compared with the nine-minute Kenmore-to-Park running time at present, represents a goal for Central Subway operations.

It has been the role of the Central Area Systems Study to point out each of the incremental steps necessary to attain this level of operating performance. The most important and most effective of these steps have all been included in the Immediate Action Program. There are other questions which must be left for resolution during the next twenty-year period. After the Immediate

Action Program has been implemented, it must be determined if and when conversion to high-platform operation is justified. Likewise, after the immediate action improvements have been placed in operation, it must be determined if and when the Copley Junction should be eliminated. Finally, as the last of the important decisions, it must be determined if the Bowdoin - Park tunnel is justified by data available at that time. It should be noted that a low priority is presently placed on this investment. Final determination may depend upon the details of reconstructing the Boylston Street Station for a possible future service through the Broadway portal.

The staged decision-making process for the Copley Junction must be based on analysis of the needs of the patrons of the Huntington Line. It was partially this consideration that led to the initial rejection of a new Huntington Avenue tunnel for the Riverside alignment. It is clear that the final solution for the Huntington alignment must stress the ability of the line to connect many destinations in the Fenway area with the rapid transit network connections available at the core of the system. This implies equipment with low-platform capabilities, with only minor need for improved line speed. For the present, the streetcar is uniquely suited for this kind of multi-destination distribution service. Chapter 11 notes, however, that this kind of service is susceptible to new technology presently under development. The most important conclusion to draw at the present is that the construction of a new streetcar tunnel before design needs of the new dual-mode technology are fully understood would be premature.

Planning on a conceptual and traffic level must continue to examine downtown investments which return significant levels of benefit and increase system patronage. Such a planning program will take into consideration the excellent source of data created in the CASS Park-Bowdoin connection analysis. Specifically, a more direct access to Post Office Square must be found. This could come either from a Green connection from the west, or a South Station connection. Additional data developed in the CASS research points out that if Northeast Corridor distribution is to be substantially improved, the very poor transfer facility at State to the Orange Line south must be improved. A proposal for testing might even examine a Blue Line routing that takes patrons closer to the retail core, an important destination for this corridor.

A Riverside corridor downtown distribution concept, which will bring about a solution to the line-haul vs. distribution dilemma,

may be possible. The Riverside corridor volumes are two-fold in need. First are those who directly benefit from the excellent distribution capabilities of the closely-spaced stations of the Green Line subway. Secondly, there exists another segment of the corridor ridership whose desire lines need to bypass this area to get much further into downtown to the lower Financial District. We have stressed the existence of an elongated western neck of downtown whose need for access effectively impedes the travel of the majority of Riverside corridor riders. Therefore, during the rush hours perhaps additional service could run express to Back Bay and on to South Station.

This split service is a distinct long-range possibility, using a single track over minimum distance.

The South Station rush hour express would not be a panacea, but it is a logical concept deserving full cost benefit consideration. Two factors tend to mitigate against its use. The construction cost from Beacon Junction to Massachusetts Avenue would be considerable, especially since this service would be designed for a distinct minority of Riverside Line daily riders. Secondly, the proposal would make use of the right-of-way from Back Bay to South Station. This is valid only if the Authority has no higher priority need for that critical segment of downtown right-of-way. The probable needs of present day express buses and future dual-mode buses for an exclusive downtown right-of-way of some kind must be carefully noted. In brief, no decision should be made in favor of utilizing this right-of-way for the Riverside patrons until a full understanding of the value of the link for other network users has been established.

SUMMARY OF THE RECOMMENDED PLANNING PROGRAM

The policy conclusions of the Central Area Systems Study, which deal with downtown alignment alternatives, can be divided into decisions made and those left to a staged decision-making process over the planning period. In the first category, policy questions that have been answered, there are four major points:

1. The Riverside Line should continue to utilize the Central Subway alignment for at least the next decade, and without converting to high platforms in Stage 1.

2. No plan should be adopted which excludes the Commonwealth or Beacon Lines from the Central Subway.

3. Rerouting the Huntington Avenue Line from Back Bay to the Broadway portal with a new tunnel under the Massachusetts Turnpike does not appear to be economically justifiable.

4. The Park to Bowdoin tunnel does not improve network performance sufficiently to justify its construction costs.

In the second category of output from the Central Area Systems Study are those policy questions which can only achieve final resolution from a program of cotinuing analysis, using information that will become available over the planning period. These areas are summarized below.

1. Given the decision to continue Riverside operations through the Central Subway, the long-term "final" plan must include a solution for the Copley Junction bottleneck. The planning process must continually monitor developments of new technology applicable to the Huntington Line and to the South End service needs.

    1a. The Huntington Line should remain in the Central Subway until a final determination of a new alignment, with equally good network connections, has been established.

2. The Authority will adopt a strategy to maximize the capacity and efficiency of the Central Subway facilities. The Immediate Action Program (in Chapter 10) describes the most important investments in this effort in terms of power, track, and signal improvements.

    Longer term considerations include the possible operation of dual-platform vehicles through a converted high-platform Central Subway. Likewise, serious attention must be paid in the design of the vehicle to minimize station dwell times. If possible, vehicles purchased in the Immediate Action Program should be designed so that convertible step mechanism could be added at such a time as conversion is deemed justified.

3. Downtown network planning must continue to explore alternative investments and their system-wide impacts. These include non-rail new technology; the problem of Post Office Square accessibility; and the use of pedestrian-oriented movement systems to improve downtown network performance.

APPENDIX

METHOD

The selection of new downtown route alignments for study was jointly made among Authority Planning Staff and Consultants (Peat, Marwick, Mitchell & Co. and DeLeuw, Cather & Company) and represent basic long-range alternatives for reducing congestion in the Central Subway by either diverting a portion of the Central Subway traffic along new routes and/or converting the Central Subway to high-platform operation.

The analysis and evaluation of new downtown routes was made using recently developed 1990 traffic estimates from other studies. The effect of the new routes on passenger travel times, passenger revenue, operating and capital costs was determined for the various downtown systems. A computer technique was developed to simulate travel on the downtown systems and measure the effects of various downtown routes for alternative evaluation. Consultant work was augmented by staff analyses of route alternatives due to contract funding limitations. These analyses consisted of in-depth analysis of alternatives studied by the Consultant and additional alternatives plus revenue and operating cost analyses. The traffic impact of the new downtown routes was evaluated for both the total downtown system and the portion(s) of the system notably affected by the new routes. The impact of new routes on passenger travel time downtown was analyzed in terms of individual time components of trips such as passenger travel time in the vehicle, passenger waiting, and transfer time expended while transferring between lines and passenger walk time to the downtown destination zones.

Evaluation of downtown systems is based on transit trips to and through downtown which originate outside the downtown area. Intra-downtown transit trips (trips which both begin and end downtown) were not included in the analysis since these trips account for less than 10% of the downtown transit activity and would add a disproportionate expense to include in the assignment model.

Analysis of the various downtown routes generated additional alternatives for evaluation which could not be included in the scope of this study due to time constraints but will be analyzed as part of the continuing planning process.

TRAFFIC ANALYSIS TECHNIQUE - DOWNTOWN ASSIGNMENT MODEL

General

The downtown assignment model, which was used to evaluate the traffic impact of downtown system alternatives, consists of a series of three computer programs which accomplish the following tasks:

1. The transit network program (NETPROG) traces the minimum time paths from the station (collector station) on each transit line located nearest the downtown area boundary line to each downtown destination zone. The program recognizes up to three different but equal time paths from origin station to destination zone and assigns portions of the destination zone to the three appropriate alightment stations on each minimum time path used to reach the destination zone. The program also computes the minimum time paths between collection stations for corridor-to-corridor trips which pass through downtown. The program computes the percentage of trips entering the downtown area, along each line, which will be assigned to each of the minimum time paths.

2. The trip loading program (LOADPROG) assigns the corridor line volumes, which enter the downtown area, to the minimum time paths and summarizes the assignments to produce line and station volumes.

3. The time summary program (SUMTIME) calculates statistics for the time elements associated with the transit trips by operating on the output of the previous two programs.

The model is divided into three programs due to capacity limitations of the Authority's IBM 360-40 machine which was used to run the model.

Input Data

The coordinate locations of the downtown destination zone boundaries and rapid transit stations are input to the model to define the static system characteristics (downtown destination zones and transit network) of each alternative system. Dynamic system characteristics are also input to the model which include service levels (running times, transfer times, headways) and the location and intensity of trip generators (trip volume distribution patterns

and activity "spikes"). All of these potential variables affect transit riding in various degrees and are thus incorporated into the model.

The 1990 "Recommended" transit network trip table was used in previous studies to develop corridor line volumes and trip distributions which were input to the downtown assignment model for all alternatives tested. This procedure establishes a constant base from which to compare the various alternatives and provides the largest line volumes which are expected to materialize in 1990. The time summary program results from the downtown assignment model were subsequently employed in adjusting the base line volumes to reflect the impact of each downtown system on traffic volumes.

The model normally treats each downtown destination zone as having a uniform distribution of trip ends (i.e., trips are evenly distributed throughout the zone). Certain downtown zones, which have pronounced concentrations of trip ends, were programmed into the model with activity "spikes" located at the specific concentrations of activity so that the model would not treat these zones as homogeneous.

Output Data

The data produced by the downtown assignment model is in both detailed and summary form. The transit network program (NETPROG) produces the following micro data:

1. Percentage of trips from each transit line to each downtown destination zone assigned to the three transit stations closest to the zone under consideration.

2. The travel time from collector station to the destination station (which is assigned the highest percentage of trips of the three selected stations) and the walk time from that destination station to the destination zone boundary for each corridor to zone interchange. This data is both printed out and stored in the computer for direct linkage to the next program (LOADPROG) in the model.

The transit trip loading program (LOADPROG) produces both micro and macro data as follows:

1. The number of trips from each transit line to each downtown station, to each downtown destination zone.

2. Directional line volumes between each pair of downtown stations.

3. The on's and off's at each downtown station.

4. The number of transfers by direction through each downtown transfer station.

The time summary program (SUMTIME) also produces both micro and macro data:

1. Running and transfer times for each transit line to each downtown station.

2. Walk times from each downtown station to each downtown zone.

3. Transit trips, line times, transfer times and walk times by transit line by station and by zone.

4. Total trips from each station to each zone.

5. Total trips from each zone to the station serving the zone.

The statistics produced by the model are condensed to provide the following downtown network evaluation data for each downtown transit line and for the total downtown system:

1. Average line time per trip (spent on and waiting for a transit vehicle).

2. Average walk time per trip.

3. Average total time per trip.

4. Transfer time as a percent of total time.

5. Walk time as a percent of total time.

CHAPTER 10

A RECOMMENDED PROGRAM FOR IMMEDIATE ACTION

THE STAGE I PROGRAM

INTRODUCTION

The previous chapters have discussed the problems with the present system and a number of attempts to solve these problems which involve major reconfigurations of the system. It was shown that major changes in the shape and character of the routes and services would be extremely costly, and in some cases, might create more new problems.

Due to the urgent need to move quickly to replace deteriorated over-aged cars, fixed equipment, and physical plant, the basic goals for system services and system development were evaluated to see what could be done to the system to achieve major improvements in a relatively short period of time, and with less investment. The basic criteria for selecting and assigning priorities to system improvements for an immediate-action program are as follows:

1) Improvements should have a large impact on the public per dollar invested.

For example, between given points on a route speed of trains could be improved by investing large amounts of money in new alignment with new tunnel or bridge construction; or similar gains in speed might be possible by spending much smaller amounts of money on track, signal, and rolling stock improvements.

2) Individual improvements should result in multiple benefits whenever possible.

For example, replacement of worn rail with new rail at proper line and grade can have the effect of reducing travel time, and improving comfort, due to a smoother ride. Another example would be the installation of cab signal system with automatic train stops which would increase reliability, reduce travel time by permitting increased speeds, improve safety of operations, and increase capacity of the system.

3) <u>Improvements should be able to be accomplished in an incremental manner</u>.

> It must be possible to make these improvements while keeping the system in full operation. It is also desirable that the improvements begin to reap benefits even when partially complete.

4) <u>All improvements should, wherever possible, leave the door open for future changes to the system</u>.

> The improvements should be compatible with possible long range changes or reconfigurations of individual routes. The improvements should serve as building blocks for the future.

The discussion in this chapter is concerned with the Green Line, since this is where most of the immediate problems lie. The principles, however, would apply to the Blue Line, or any other part of the system. The only Stage I recommendation for the Blue Line is the acquisition of 32 new rapid transit cars to replace the 48 existing cars built in 1923 and 1924, and the installation of radio communication on that line.

In Chapter 4, it was concluded that no new extensions or line changes for the Blue Line should be undertaken as part of an immediate action program. The need for new cars, however, is painfully obvious. During the CASS study, serious consideration was given to the possibility of constructing a through connection between the Blue Line and the Riverside Line, (see Chapter 9). The creation of such a through route would have had an influence on the design and quantity of any new cars for the Blue Line. Since it now appears unlikely that a Blue-Green connection will be constructed in the forseeable future, if ever, there is no reason to delay further with the acquisition of these badly needed cars. If an extension is constructed from Wonderland to the Pines River area within a few years, it will be so short that it will have no significant effect on the total Blue Line car fleet requirement.

Analysis of the problems of our present Green Line facility and the way it is operating, and the possible means of improving it, was done by defining the basic needs of the people who use it, and following this with a detailed investigation of the many approaches to meeting these needs. The needs for Green Line system and service improvements may be summarized as follows:

I. Reduce overall travel time.

II. Improve reliability of service.

III. Improve rider and community environment

IV. Improve safety and security.

V. Increase system capacity

VI. Control cost of operation

This chapter treats each area by breaking down the problem into basic components, and individually treating the solutions to each. Due to the nature of many of the problems and answers to them, a certain amount of repetition has been necessary. However, this serves to point out how one change in the physical plant can benefit the user in several ways. The chapter concludes with a summary of the elements proposed for the improvement program with estimated costs, but organized by categories of hardware, or physical change. The Stage 1 Program is based upon the acquisition of a new fleet of Green Line Cars.

The goal-oriented description sets forth a framework for the Authority to use in carrying out the specifics of this recommended program. It also suggests some directions for minor service or facility improvements, as part of our normal programs for system operation and maintenance. In addition, it points out areas where improvements by other agencies, for street traffic for example, may be guided, to help improve service for the Green Line riders.

This Chapter is broken down to seven major headings, covering the six needs, or performance goals, listed above, and a summary of the recommended "Stage I" action program. Following is a full outline of the Chapter.

OUTLINE OF CHAPTER 10

I. Reduce Overall Travel Time
  Introduction
  A. Increase Running Speed
    1) Rolling Stock Improvements
    2) Track, Roadway and Structure Improvements
      a) Improvements within the confines of the Existing Right-of-way and Structures
      b) Improvements Requiring Major Deviation from the confines of the Existing Right-of-way or Structures.

3) Signal System Improvements
4) Power System Improvements

B. Reduce Number of Station Stops
1) Elimination of Subway Stops
2) Elimination of Surface Line Stops
a) Beacon Street Line
b) Commonwealth Avenue Line
c) Huntington Avenue Line
d) Highland Branch
3) Skip-Stop and Limited Stop Service

C. Reduce Duration of Stops
1) Rolling Stock Improvements
2) Station Improvements
3) Fare Collection Procedures

D. Reduce Unnecessary Waiting Due to Congestion at Junctions and Intersections.
1) Subway Junctions
2) Surface Street Intersections

E. Summary of Total Benefits

II. Improve Reliability of Service
Introduction
A. Reduce Frequency of Delays
1) Reduce Failures of Rolling Stock and Facilities
a) Rolling Stock Failures
b) Track, Roadway and Structures
c) Signals, Communication and Power
2) Reduce Random Conflicts with Operations
a) Reduction of Internal Conflicts
b) Reduction of External Conflicts

B. Reduce the Duration of Delays
1) Provide New Means of Detecting Delays
2) Provide New Means of Taking Corrective Action

C. Summary of Total Benefits

III. Improve Passenger and Community Environment
  Introduction
  A. Passenger Environment
    1) Improve Ride Quality
    2) Improve Ventilation, Temperature and Humidity Control
    3) Reduce Noise Levels
    4) Improve Interior Layout and Finishes

  B. Station and Right-of-Way Environment
    1) Reduce Noise Levels in Tunnels and Along the Right-of-Way
    2) Improved Maintenance of Rights-of-Way and Facilities

  C. Summary of Total Benefits

IV. Improve Safety and Security
  Introduction
  A. Provide Automatic Train Stop Capability
  B. Improve Surveillance of Trains and Stations
  C. Reduce Conflicts with Pedestrians and Automobiles
    1) Improve Pedestrian Safety
      a) Pedestrian Signal Installations
      b) Median Fencing
      c) Elimination and Consolidation of Stops
    2) Improve Vehicular Safety
      a) Vehicular Crossovers
      b) Curb Barriers
  D. Summary of Total Benefits

V. Increase System Capacity
  Introduction
  A. Increase Capacity of Vehicles and Trains
  B Increase Capacity of Infrastructure
    1) Description of Copley Junction
    2) Factors Limiting Capacity of the Junction
      a) Degree of "Parallel Moves" through the Junction.
      b) Speed of movement through the Junction.
      c) Length of Train Operated through the Junction.

    3) Proposals for Improvements
      a) Automatic Traffic Control
      b) Gauntlet Track Layout
      c) Increased Train Length
    4) Other Signal and Operational Improvements
  C. Summary of Total Benefits

VI. Control Cost of Operation
Introduction
A. Reduce Cost of Normal Scheduled Operations
B. Reduce Maintenance Costs
C. Reduce Costs Incurred by Abnormal Operations
D. Summary of Benefits

VII. Stage 1 Improvements - Summary and Estimate

I. REDUCE OVERALL TRAVEL TIME

INTRODUCTION

"Overall travel time" includes not only the time spent on the transit vehicle in motion, but also time spent by a train standing in stations or at junctions or street intersections, and time spent by passengers walking to or from a station, waiting at a station, and transferring from one vehicle to another.

One of the major factors affecting choice of transit over automobile is relative travel time of the two modes of travel. The present Green Line system has certain built-in restraints affecting travel time which could only be corrected by massive reconstruction. Fortunately there are many areas of the fixed facility, rolling stock, and method of operation which can be improved at reasonable cost. In fact this family of improvements will buy considerably more benefit per dollar invested than would improvements requiring reconstruction or relocation of the fixed plant.

The Green Line system does have some built-in advantages when overall travel time is considered. As the system combines the functions of suburban collection, line haul, and downtown distribution in a single vehicle, giving in most cases a "one seat"ride without transfer, it has the potential of offering many riders overall "door-to-door" travel times which would compare favorably with rapid transit with connecting feeder bus service in other corridors.

The improvements discussed in this section will buy time savings which can be applied to reducing the average travel time for most users, and can be used to provide a margin for smoothing out irregularities in the operation of the system. The pure travel time savings which will apply to a majority of the users of the Green Line system (both those who originate on it and transfer to it from the other lines) will not only help retain the present ridership but also attract new riders.

The system improvements described below will concentrate largely on those items over which the Authority has some control. They include the need to:

A. Increase running speed.

B. Reduce number of stops.

C. Reduce duration of stops.

D. Reduce unnecessary waiting due to congestion.

The means for meeting these needs may include improvements which may be done independently of other improvements, and those which must be made in conjunction with others in order to be effective. An example of the former would be the elimination of a station stop, while an example of the latter case is the need to upgrade track, power, and signals in order to take advantage of the high speed capability of a new car fleet.

A. INCREASE RUNNING SPEED

Increase of running speed will result in substantial time savings, particularly on the Highland Branch where stations are well spaced and there are no conflicts with street traffic. As this is the longest line on the system it needs all the help we can give it. More than any of the other parts of the Green Line, the Highland Branch suffers the most from the restricted maximum speed capability of the present PCC cars (about 37 mph), the restrictions imposed by condition of the track, and the built-in limitations of the power supply and signal systems.

Improvements in running speed are desirable on the other branches of the Green Line, though there is less latitude for possible improvements due to closeness of stops and presence of grade crossings. Some increase in speed in the subway is also desirable, and is possible except in certain areas where reconstruction at great cost would be needed to accomplish major improvements.

Improvement in acceleration capability however can achieve time savings on the surface branches and in the subway.

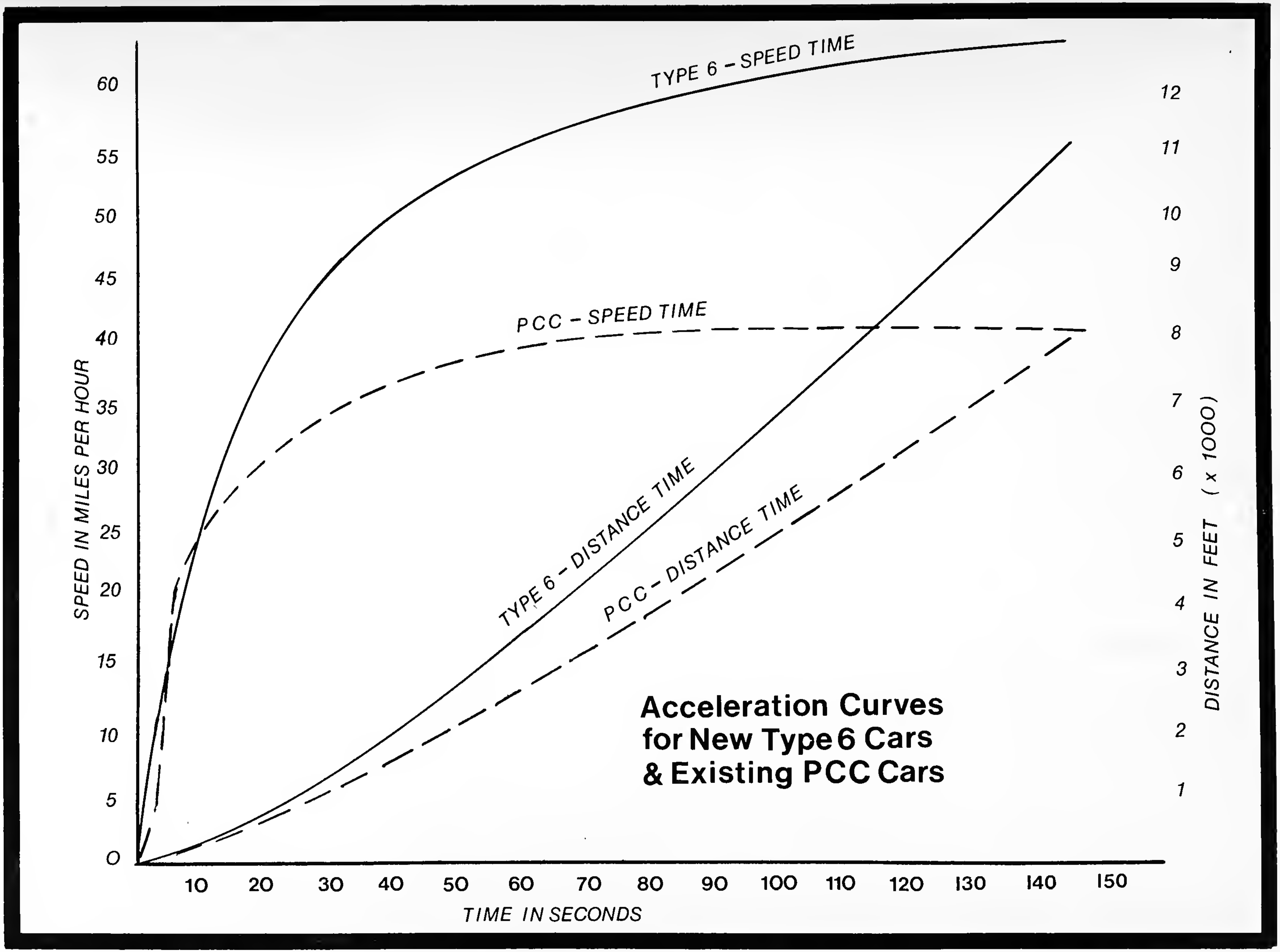
Increases in running speed, and particularly increases in top speed, require investment in both rolling stock and infrastructure. Doing one without the other will not give the desired results in terms of travel time reductions. A description of the various means of increasing running speed follows below.

1) Rolling Stock Improvements

The performance of a rapid transit car, in terms of speed and running time capability, is a resultant of its rate of acceleration, deceleration, and maximum speed. Maximum speed is normally expressed as "balancing speed" which is the speed the car would reach on level, tangent track with no wind. To reduce travel time one should improve not only the top speed, but also shorten the time it takes to reach this speed from a stop, and the time to slow down to a stop.

In the normal operation of high performance rapid transit cars, on a route with average station spacing, the train spends most of its time accelerating or braking, and only when station stops are several miles apart, can the train reach its balancing speed. The natural characteristics of the propulsion equipment provide a high and fairly uniform rate of acceleration at start and through the lower speed range, up to roughly one-half the balancing speed, at which point the acceleration rate decreases at an ever increasing rate until it flattens out to reach the "balancing speed". (See Figure 10-1 showing speed-time, and distance-time curves for PCC and new cars.) The characteristics of the braking system is somewhat different as a nearly uniform rate of deceleration can be achieved from maximum speed to full stop.

The existing PCC cars, when new, could achieve a balancing speed of approximately 42 mph. Initial acceleration rate was 3 mphps (miles per hour per second) and the same for braking. They would reach 30 mph in about 20 seconds and 600 feet of travel, and 40 mph in 65 seconds and 3,000 feet. (This is based on a single car with a seated load of 42 passengers, on level tangent track.) As the PCC was originally intended for street railway operation it was not designed to run for longer distances at its maximum speed. Thus it was found necessary to limit the speed to 37 mph, so the present performance is not as good as shown in the examples above.



TYPE 6 – SPEED TIME
PCC – SPEED TIME
TYPE 6 – DISTANCE TIME
PCC – DISTANCE TIME
Acceleration Curves
for New Type 6 Cars
& Existing PCC Cars
SPEED IN MILES PER HOUR
60
55
50
45
40
35
30
25
20
15
10
5
0
DISTANCE IN FEET (x 1000)
12
11
10
9
8
7
6
5
4
3
2
1
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
TIME IN SECONDS

FIGURE 10-1

While the CASS study project was in progress, the Authority's Equipment Engineering and Maintenance Department prepared preliminary specifications and drawings for a new Green Line car which would be adaptable to operation on the surface and in the Central Subway without major alterations to the subway structure or stations. The design was based upon information developed by the CASS Project but was done independently. It became known as the "No. 6" car design, and a full-scale mockup of a section of a No. 6 car was constructed at the Authority's Everett Shops.

The No. 6 car design has shown that an excellent car can be constructed for Green Line service which will alleviate many of the existing problems of operation, and with performance and comfort characteristics that will approximate those of the most modern high-platform rapid transit cars. The performance characteristics of the No. 6 car were used to arrive at projected running times and required quantity of cars. No decision has been reached on the exact design of vehicle that will be adopted, however. The Authority is investigating other designs, including several that are in general use in European cities. These European cars are giving highly satisfactory service in cities which have conditions quite similar to those in Boston.

Whatever configuration of car is ultimately selected for use in Boston, its performance will undoubtedly be comparable to the No. 6 car. The No. 6 car design therefore serves as a good example of what can be accomplished, and will be referred to repeatedly throughout this chapter.

The No. 6 Green Line cars will have performance specifications calling for a balancing speed of 65 mph when in a train of two or more cars, and 59 mph as a single car. This represents roughly a 50% increase over the present PCC cars. The initial acceleration rate will be the same 3 mphps as a PCC but it will maintain it for a longer period of time. The braking rate will be 2.8 mphps above, 45 mph and 3 mphps below that speed. Thus the new car, in train formation, could reach 40 mph in about 23 seconds and a distance of 900 feet, and 55 mph in one minute and a distance of about 3500 feet.

The improved performance is made possible by providing 100 hp motors (4 per car) in lieu of the 55 hp motors on the present PCC cars. These motors, of course, will consume more power when operating at higher speeds, but the extra cost of power will be more than balanced by savings due to increased productivity of the cars and crews resulting from the reduced running times.

The performance level of these trains, while on the Highland Branch, will approach that of the new South Shore cars. Though the latter

have a slightly higher balancing speed, they have a lower acceleration capability. On the run from Kenmore to Riverside, the present peak hour run time of 31 minutes will be reduced by the new cars by 8-1/2 minutes to 22-1/2 minutes, assuming 20 seconds dwell time at all present stations. On the other surface lines, the maintenance of the initial acceleration rate for a longer time will allow some reduction in travel time. On these routes, and in the subway, the improved performance can be useful in providing more recovery time to make up for delays.

2) Track, Roadway and Structure Improvements

Improvements in these areas are necessary to permit the higher speed capability of the new cars to be fully utilized, and to improve passenger comfort. Improvements can be carried out within the confines of the existing roadbed or tunnels, by modifying the track design, and by upgrading the track, or may be accomplished by major deviations from the existing facilities.

a) Improvements within the confines of the existing right-of-way and structures:

As the maximum speed in the subway and on the reservation routes will not be much greater than what was possible with the PCC cars when new - approximately 40 mph - modification of track or structure are not required for running speed improvement. Work must be done in these areas, but primarily to improve comfort and reliability, and reduce congestion.

On the Highland Branch the new cars will be able to operate at considerably higher speeds than at present, once certain improvements are made. There are three basic problems with the present facility: first, the track geometry was originally planned to accommodate steam locomotive-hauled trains of limited acceleration capability with a maximum speed over most of the line of 45 mph; second, when purchased by the MTA, a minimum amount of money was available for upgrading track and replacement of worn-out facilities; and third, the track has not been maintained to sufficiently high standards.

Fortunately the existing alignment is not all that bad, and offers considerable scope for upgrading without major changes in track location.

Ignoring the effect of station stops and grades on the performance of the car, the feature of the track which dictates the speed which a car is allowed to run is curvature. The speed on a curve is dictated by the radius of the curve and the superelevation, or banking, of the curve. Superelevation is expressed as the number

of inches that the outside rail of a curve is raised above the inside rail. The speed limits prescribed for curves are largely based on comfort factors, with the maximum safe speed being considerably higher than that imposed by comfort criteria.

The superelevation of a curve is set in ideal conditions, when the centrifugal force imposed upon a person seated on the train would be transmitted downward in a direction perpendicular to the seat, so that he would feel no sideways force. This is known as a balanced or equilibrium condition. Actually it is possible to run at a faster speed and experience some sideways force without feeling discomfort. For example, with curves superelevated at the maximum limit of 6" (the maximum comfortable sideways slope in the car floor for a train stopped on such a curve) it is possible to run on well maintained track at a speed approximately 27% higher than the speed that would produce the equilibrium condition. This amounts to the speed permitted by a theoretical superelevation of 9-1/2". (The difference between the 6" max. and the 9-1/2" of 3-1/2" is known as "unbalance".)

There is a further limit on raising the superelevation imposed by comfort criteria based on the allowable rate of change of superelevation and curvature. Too abrupt a change in superelevation will give a rough ride, particularly to standees. In addition, as a curve is entered, the radius must be varied over a distance of several hundred feet to provide a smooth transition from a straight line to a circular path of motion.

Analysis by the consultant and staff has indicated that increasing the superelevation, along with replacing worn material in the track, and realigning and regrading the track to meet higher speed standards, will permit a speed of 53 miles per hour. The sharpest curve on the Branch, outside of yards, is just east of Brookline Hills Station. When improved, it will have a speed limit of 38 mph, but it is short enough and close enough to the station that this speed is not reached until the train has passed over the curve.

The area between Brookline Hills and Brookline Village, as well as several other spots along the line, incorporate physical restrictions such as walls, or bridge abutments, which make it difficult to achieve large increases in allowable speed. Urban renewal of this area is under consideration, and if a project is established, the Authority should try to improve the track alignment. See Exhibit 22 in Volume III.

A special area, the Reservoir Upper Yard, should be rebuilt to eliminate speed restrictions. Here a different operating pattern should be established once new cars are in service. These cars, with their ability to operate in either direction, will offer enough flexibility that it will be possible to make these changes.

The exact scope of the work required to improve the quality of the track itself is described in the consultant's report, Volume II.

The improvements in track and roadway on the Highland Branch will result in the following speed limits due to track geometry.

Allowable Speed in Miles Per Hour	Length of Line in Feet	% of Total Distance Riverside to Fenway
60 or above	37,400	76.4
50 to 59.9	9,850	20.1
40 to 49.9	700	1.4
30 to 39.9	450	0.9
Below 29.9	600	1.2
Total Length Riverside to Fenway	49,000	100

b) Improvements Requiring Major Deviation from the Confines of the Existing Right-of-Way or Structure:

The Immediate Action program has been limited to roadway improvements within the present right-of-way or structures because of the high cost of modifying subway tunnels, bridges, or retaining walls. The rehabilitation of the Highland Branch track to permit higher speeds as well as greater comfort, safety and ease of maintenance, will cost approximately $330,000 per mile. This may be compared with new subway construction at $25 to $30 million per mile - nearly 100 times the cost.

The physical realignment of the existing subway to improve speed is an extremely expensive way of buying time savings. To double the speed on a curve requires quadrupling the radius, assuming that the same superelevation is used in both cases. The present curve at Boylston Station from Tremont Street to Boylston Street has an 85' radius which permits a speed of approximately 12 miles an hour. To double the speed the radius would have to be increased to 340' which would require the construction of approximately 530' of new subway tunnel. This work would be complicated by the fact that each end of the tunnel must connect into the existing subway with the construction work being done while train service is maintained over the old alignment. This improvement would only save approximately 15 seconds, and if we assume that this construction work might run a cost of approximately $6,000 per linear foot we would be spending the equivalent of $12 million per minute of running time saved.

Another example of the high cost of buying time savings with major new changes would be the conversion of a present surface line to subway. If, for example, a part of the Commonwealth Avenue or Beacon Street lines were converted from a reservation operation to a subway, the capital cost could amount to $20-$40 million per minute of running time saved. A rough calculation of the time saved by running a fleet of new cars on the Riverside line with accompanying track, signal, and power improvements would result in a capital cost of roughly $3-$4 million per minute saved.

Fortunately, many of the immediate action improvements that result in a reduction in travel time will have other benefits such as improved ride, safety, increase of line capacity, and stabilization or reduction of operating costs.

Major changes to infrastructure, such as the replacement of surface reservation with subway as described above, could actually increase travel time for certain groups of riders. To maintain higher speed, and reduce capital costs, a mile of new subway would have fewer stops than the mile of surface reservation. Thus walking time to stations could be increased, or if the subway was built with very long station spacing, many riders would be forced to use a parallel feeder bus service with additional wait and transfer time.

3) <u>Signal System Improvements</u>

A serious problem with the present Green Line system is the outmoded signal and communications systems. Unlike the signalling on the rapid transit lines, the Green Line has no automatic train stop control which stops a train if the operator passes a red signal. Because of the characteristics of the present signals, it is necessary to limit speed to 35 to 40 mph, which gives relatively short stop distances, and has a reasonably good safety record. As we desire to increase the maximum speed on the Highland Branch to 60 mph, and improve the capacity and reliability of the signal system within the subway, the Phase I program includes a complete replacement of the existing signal system.

Among the many benefits to be derived from a new signal system will be an improvement in the permitted running speed between stations. This will be accomplished by the application of a continuous cab signal type command passed down the running rails into the trains affected. The benefit derived from this system is that as conditions change or improve on the trackage ahead, the command to proceed at a greater speed will come simultaneously and not only at intermittent wayside locations. In addition, an improved scheduling and train spacing will be policed by the signal system which will result in a more evenly spaced arrival of trains at stations. This of course will permit a more orderly travel of

trains between stations with a minimum of delay due to the preceding train. Also, improved route selection for track switches will eliminate the requirement for the train to stop or slow down at junctions and interlockings.

The new signal system will police proper train spacing more rigidly by means of initial dispatching of trains from the end terminals, and intermediate rescheduling at key locations, such as the last stop of feeder lines before entering the common tunnel area. By this means, it will be possible to control train movements into the common tunnel area. Unless the train can properly merge with the already existing trains in that area it will be held at the last stop until the train can merge smoothly with the existing traffic. It will also be possible to control these junctions in such a way that a preference can be given to any one line or that trains enter on a first-come, first-serve basis. Under no circumstances will the system permit that any one line establishes absolute priority and therefore shuts out all other lines.

With trains entering stations at a more orderly spacing, it is expected that each train picks up its share of passengers. As this should limit the amount of passengers assembled for each train prior to arrival, the station dwell-time should also be reduced.

4) <u>Power System Improvements</u>

The power system which feeds the present Authority network consists of: 1) power stations which generate AC power, 2) AC transmission lines connecting the generating stations with, 3) substations which convert high voltage AC power to 600 volt DC power necessary to run the trains, 4) DC feeders connecting the substations with, 5) the trolley wire and third rail. Tie-lines and switchgear permit various interconnections of the AC networks, and of the DC networks so that loads may be shared, and trouble spots may be bypassed.

Much of the system is old, dating back to the days when there was a large surface rail network. In a number of areas substations are some distance from the lines and loads which they feed resulting in losses in efficiency. The performance of the present Green Line system, and particularly the Highland Branch, suffers from inadequacies of the power system. In spite of the emergency tie-lines, temporary loss of a substation or major

feeder can result in suspension of service over parts of the system. On the Highland Branch, due to limitations on funds when it was constructed, the line voltage is often just barely high enough to run the trains. As a result speed and acceleration are limited, and in the winter heating of cars is very restricted.

The provision of new cars will require additional substation and feeder capacity and modifications of the trolley system. This is necessary because the higher speed operation, made possible by higher horsepower motors which maintain a high rate of acceleration over a longer period of time than the present cars, use more power, as do the auxiliaries such as air conditioning, train radio, and cab signals, which are not on the existing PCC's.

It is proposed in the immediate action program to provide 3 new substations, with associated feeders, for the Green Line. One at Riverside will feed the outer end of the Highland Branch, and the enlarged Riverside shop and yard. Substations at Chestnut Hill and Fenway will feed the Highland Branch, and the latter will tie into the Beacon and Commonwealth lines. These will permit a considerable improvement in performance and reliability of the entire Green Line and will allow for future traffic growth in the corridor. Alternative locations for two of the substations, preferred by the engineering consultant, DeLeuw Cather & Co., are at Hammond Pond and Reservoir. See Volume II.

Improvements in the overhead trolley system on the Highland Branch will be needed to permit higher speed operation. The realignment of track and increase in superelevation on curves will require that the trolley wire be realigned as well, to keep the wire lined-up with the center-line of the cars. For the most part, this work can be done without relocating the supporting poles.

Areas which will deserve some special attention are at low overbridges where the trolley wire is depressed below its normal elevation above the track. The Centre Street overpass between Newton Highlands and Newton Center is the worst condition, causing a speed restriction for the present operation. To improve speed at such locations it will be necessary to ramp down the trolley wire over a longer distance, and in the case of Centre Street, lower the tracks somewhat. In addition, the trolley suspension system will have to be modified to provide a softer, more flexible support under the bridge, to eliminate the hard spots which can jar the trolley off the wire at higher speeds. There is some

new technology in this area which has been developed for high speed electrified railways. Similar treatment is necessary at several spots in the subway to eliminate speed restrictions.

The consultant has suggested that it could be desirable to replace the entire trolley system on the Highland Branch with a more elaborate catenary system to achieve a smoother vertical profile and horizontal alignment of the trolley wire. However, the present poles and trolley system are relatively young on the Highland Branch (built in 1959), and are in reasonably good condition. The capacity of the trolley and bulk of the feeder system is sufficient to handle the electrical loads of the new cars, once new substation capacity is installed. Thus, the additional electrical capacity offered by a more complex catenary system is not required.

There is a considerable body of experience with high speed operation on simple trolley wire with trolley poles. Electric interurban railways operated multi-car trains at speeds in the 60's and 70's nearly fifty years ago. The Authority has made test runs with existing cars at 50 mph on parts of the Highland Branch without any trolley difficulties.

Based on these factors, we conclude that operation in the 55 to 60 mph range will be practical on our existing trolley system, with the modifications at bridges and curves described above, along with the new substations. More detailed study may indicate that a catenary type suspension might be practical at the sharper curves since it will be necessary to make other changes in any case. This might amount to 10% to 20% of the total length of the Highland Branch, at the most.

The question of use of pantographs rather than trolley poles has been investigated by the Authority staff. It found that pantographs are not needed for the increased electrical load, nor for the increased operating speeds. Pantograph operation would require extensive modification of the entire trolley system and modification to existing cars for pantographs, or development of special arrangements for joint operation of both poles and pantographs on the same wire during the transition period. This would be extremely costly, and is not justified.

B. REDUCE NUMBER OF STATIONS STOPS

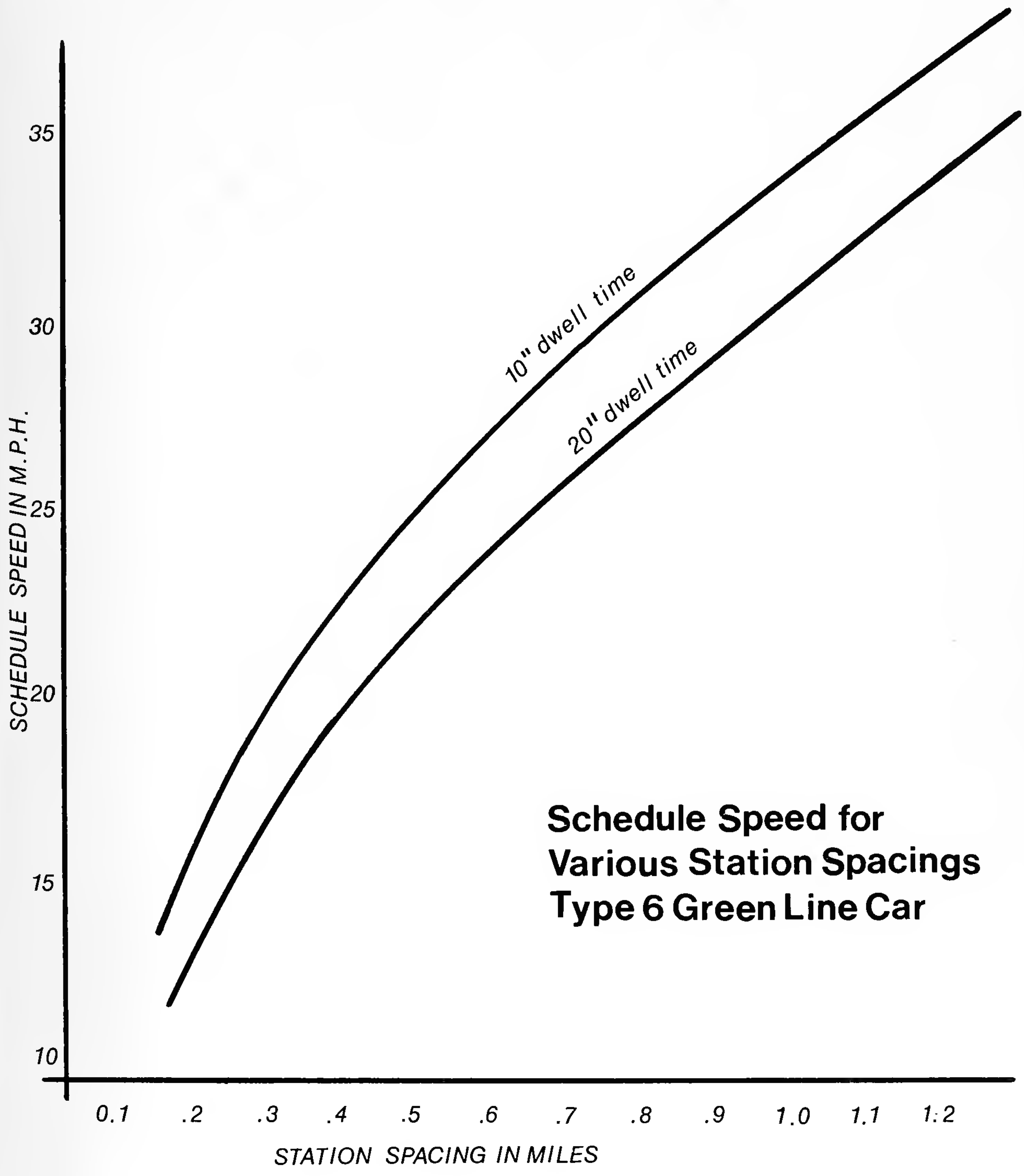
The elimination or consolidation of stops can contribute to the reduction of overall travel time for the majority of riders. However, when dealing with an existing system, there is considerably less freedom for adjusting station or stop locations to optimize travel time and accessibility than is possible when dealing with a proposed new system. Any

proposal which might upset well established travel patterns must be carefully studied, as a minority which is inconvenienced is far more vocal as a rule than a majority which is benefited by a change. It is essential that the saving in travel time to one group is not outweighed by addition to the travel time for those who would walk a longer distance to a stop, assuming that they can get there at all.

A major inhibition to making large reductions in travel time, eliminating stops, is that passengers place a higher value on time spent walking to a stop, or waiting there, than they do on the time spent riding on the vehicle. Modal split studies indicate that one minute of walk, wait or transfer time is the equivalent of 3 to 5 minutes of riding time. Thus, a heavy-handed program of stop elimination could add greatly to the apparent travel time, resulting in a serious loss of riders.

The actual time saved by eliminating a stop consists of the time spent braking to a stop, the dwell time at the stop, and the time used to accelerate back to speed. Assuming a dwell time of 20 seconds, the time saved by eliminating a stop on a portion of the route where the maximum speed is 35 mph, is approximately one-half a minute, and where the top speed is 60 mph the time saving is approximately one minute. These calculations are based on performance characteristics of the new Green Line car. The effect of station spacing on the "schedule" speed for these cars (that is the travel speed from origin to destination station with acceleration, running, braking, and dwell times included) is shown on Figure 10-2. For example, with an average station spacing of 0.2 miles and a 20" dwell time, the schedule speed would be 13 mph. Doubling the spacing to 0.4 miles raises the speed to 20 mph, while tripling the spacing raises the speed to 24 mph. Thus it can be seen that the savings in travel time made possible by reducing the number of stops is limited, though, when combined with the other improvements, a number of small savings can add up to make a noticeable improvement.

Two basic areas were considered for elimination or consolidation of stops--the subway, and the surface routes. In the case of the former, it has been found to be impractical to eliminate any stations, but on the surface routes, rearrangement of stops is practical and can result in some reduction in travel time. The analysis of these areas follows below.



35
30
25
20
15
10
SCHEDULE SPEED IN M.P.H.
10" dwell time
20" dwell time
Schedule Speed for
Various Station Spacings
Type 6 Green Line Car
0.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
STATION SPACING IN MILES

FIGURE 10-2

1) Elimination of Subway Stops

Elimination of a station between Kenmore and Park Street, although it might benefit riders from the west coming to Park Street or beyond, would seriously inconvenience those passengers from the west, and those who transfer to the Central Subway from other rapid transit lines, who use the intermediate stations for downtown distribution. One of the Central Subway's biggest advantages, the adequate coverage of the Back Bay area, is for some people a disadvantage, in that they must ride on trains that make more stops.

It is interesting to compare the station spacing on the Green Line between Kenmore and Park Street with the station spacing on the other rapid transit lines over a similar distance. We find that the Green Line has twice as many stations in this distance than any other line except the Orange Line north. What is critical is that the intermediate stations (Auditorium, Copley, Arlington, Boylston) have a total station activity which is 3 to 5 times that of the stations on the other lines within the same distance of downtown. This indicates that the Green Line is doing a lot of work in this area and any proposals which would decrease the number of stations, would reduce this effectiveness of the line.

One of the proposals for the long range upgrading of the system suggested the elimination of Boylston Station as a means of improving travel time. The discussion of easing curves in the subway indicated that major construction is required to accomplish a relatively small saving in travel time. Elimination of the station, of course, would save more time at that location, but could very well add to stop times at Arlington and Park Stations which are already critical. Proposals now under study by the BRA indicate that the area adjacent to Boylston Street Station may undergo a considerable increase in density, adding to the number of riders served by this station. Thus, it would be foolish for the Authority to eliminate a stop to accomplish minor savings in travel time and throw away the possbility of attracting many new riders, as well as keeping present riders who might desert us if their station was taken away.

The volume of present and expected future traffic, the relationship between stations and downtown development, and the need for transfer connections with other rapid transit, railroad and bus lines, precludes the elimination of any of the other stations.

2) Elimination of Surface Line Stops

Reduction of overall travel time can be brought about by reducing the number of stops on the surface reservations. Over the years

a less than optimal pattern of stop locations has developed in a piecemeal manner. Bruce Campbell & Associates carried out a study of the Beacon Street Line in 1969 and the Authority staff conducted a study of the Huntington Avenue reservation. These studies indicated that a number of stops could be eliminated or consolidated with other stops, which would result in increased speed and improved regularity of service, with a minimum of inconvenience to those walking to the stops. It is important to note that in the case of surface line stops, all trains do not necessarily stop at every stop, particularly in the off-peak periods. Thus, time savings must be based upon the average number of stops actually made by the trains.

a) Beacon Street Line:

There are seventeen passenger stops outbound along the 2.3 mile surface route, a rate of seven scheduled stops per mile. Running and overall speed between each passenger stop were determined from speed and delay data. Analysis of running time between stops revealed several sections with low running speeds, apparently caused by short distances between stops. Trains cannot reach their optimum operating speeds in these short distances.

Analysis of the speed and delay and boarding and alighting data, produced by Bruce Campbell & Associates, revealed a given number of passengers at a large number of stops require more service time (stopped time per passenger) than if the same number of passengers were concentrated at fewer stops. Fewer stops should reduce stopped time per passenger and decrease overall running times.

In their May 1969 report entitled, "Surface Car Line Operating Study - Beacon Street-Green Line," Bruce Campbell & Associates recommended that to provide a balanced system with concentrated passenger usage, the following passenger stops be discontinued:

1. Carlton Street
2. Winchester Street
3. Brandon Hall
4. Winthrop Road
5. Strathmore Road

Most of these stops lie within 300' to 500' of an adjacent stop and can be eliminated without seriously affecting walking distance. The present average distance between stops would be increased from 770' to 1,080'.

It is estimated that any loss in passengers due to the consolidation of stops (increased walking distance for some people) should

be more than compensated by improvements in running time along the surface portion. An estimate of the time saved by consolidation of these stops would be up to a minute and half per train during the peak hours.

The Authority should give serious consideration to the above recommendation, as there is little passenger usage at these stops, especially Carleton Street, Winchester Street and Winthrop Avenue.

b) Commonwealth Avenue Line:

A detailed traffic engineering study has not been made for this route as it is desirable to test the improvements recommended by the Bruce Campbell study on Beacon Street and apply the experience gained there to the Commonwealth Avenue Line. The stop spacing on this route is not as close as on Beacon, the average being 860' (770' on Beacon), with fewer examples of very short spacing. If the 25 stops within the length of 4.1 miles were consolidated to raise the average spacing to that proposed for Beacon Street (1,080'), approximately five stops would be eliminated or merged with adjacent stops. This could result in a time saving of up to 1.5 minutes for each peak hour train.

In studying this route, coordination is needed with both the City of Boston and the Town of Brookline.

c) Huntington Avenue Line:

The inner end of Huntington Avenue Line from the intersection of Huntington and South Huntington Avenues to the subway portal has been studied in conjunction with the BRA Fenway urban renewal project. This portion of the Huntington Line, connecting the extensive hospital, school, and institution area with downtown and with the other rapid transit lines, is recommended for thorough upgrading. The outer end of the line, beyond Huntington and South Huntington (or South Huntington and Heath Street), which lies completely in the paved street, is recommended for replacement by buses.

At present, there are 12 stops along the 1.4 mile long inner end of the line, giving an average spacing of 680'. The study has indicated that it is possible to eliminate and relocate stops to reduce the number from 12 to 8, giving an average spacing of 1,070'. It is estimated that elimination of these stops will result in a travel time saving for peak hour trains of 1 to 1.5 minutes.

d) Highland Branch:

The Highland Branch, with stops located on the site of former railroad stations, has a completely different character in terms of

station location and spacing than that of the surface reservation lines. In the 9.2 mile length from Fenway to Riverside there are 13 stations with an average spacing of 4,050', just over 3/4 mile. This is roughly five times the present stop spacing on the other surface routes.

Elimination of an individual station on the Highland Branch can save more travel time than elimination of an individual stop on a surface line, as the top operating speed is higher, and will be still higher with the new cars. On the other hand, elimination of a station on the Highland Branch, in most cases, would result in more serious inconvenience to the persons using the station as it would put them far beyond a reasonable walking distance of another station. On Beacon Street consolidation of stops would add no more than 200' to 300' (less than 1 minute walk time)walking distance for the average person whose stop was eliminated. Elimination of a station such as Eliot would add over 2,000' to the average walking distance, which is a considerable deterrent to using the system and, therefore, is not recommended, even though the elimination of Eliot was assumed in the 1990 traffic forecasts (see Chapter 3).

The one station which it may be feasible to eliminate is Beaconsfield, which would save just under one minute running time. This is the lowest volume station on the line, handling just over 2% of the average weekday traffic (the average for all stations being about 8%). This station is reasonably close to the Dean Road stop on the Beacon Street Line. Thus, riders from the area south of the Highland Branch would have approximately 750' additional walk, plus additional riding time on the Beacon Line (6 to 9 minutes). A rough calculation of travel time changes for the affected users indicates that elimination of the stop would save over three times the "rider-minutes" (one rider saving or losing one minute) of travel time than those now using this station would lose.

Elimination of this station should only be done after the traffic engineering improvements have been made and new cars have been placed on the Beacon Street Line, so that travel time penalties are not too severe. Also, the form and density of proposed development on the Beaconsfield Hotel site must be established, so that its effect upon ridership of the two adjacent rail lines can be determined.

Although there are several other locations on the Highland Branch where stations are closer spaced than what would be desirable for a high speed operation, the volumes of traffic they handle, the inability to provide suitable alternative service, and the kinds of present and future land use they serve, fully justify their continued use and improvement.

3) Skip-Stop and Limited Stop Service

A number of rapid transit systems have instituted skip-stop, or limited stop service. With skip-stop service stations are divided in three groups: those served by all trains (generally several miles apart), those served by "A" trains, and those served by "B" trains. The A and B stations are normally interspersed in an A-B-A-B,etc., pattern so that trains stop at every other station. This system has been used largely where stations were 1/3 to 1/2 mile apart (compared with 3/4 mile on the Highland Branch). The all-stop stations serve heavier traffic loads and give local passengers from A stations a chance to transfer to trains serving B stations.

An investigation of the use of A-B skip-stop service on the Highland Branch has been made. It assumed that a typical skip-stop service would have Riverside, Reservoir and Fenway Park as all-stop stations. Each A and B train would skip 5 of the 10 other stations on the line. With the new cars approximately 4-1/2 minutes could be saved over normal local service, assuming that trains could bypass stations at the maximum speed which the track geometry would permit. However, it is felt that with grade crossing of pedestrians and trains at stations, with trains running every 4 or 5 minutes in each direction, it is not safe to permit full speed operation through stations. If the speed were restricted to 35 mph through stations the time saving is reduced to 3'-20", while with a 15 mph limit the saving would be 1'-40".

The savings in passenger minutes were calculated for the first alternative, or best case. A.M. peak period passengers were assigned to A and B trains, and a basic headway (interval between trains) of 4 to 5 minutes at the all-stop stations was assumed. This means that the headway at A or B stations would be 8 to 9 minutes. Running time from each station to Fenway was added to an average waiting time of 1/2 the headway of each station, and the sum of these was multiplied by the number of passengers boarding in the A.M. peak period. A similar calculation was made for conventional local service and it was found that the A-B skip-stop service, at its theoretical best level of performance, reduced total passenger minutes by only 7%. The reason for the relatively small saving in passenger minutes, when the running time saving was 22%, is the penalty imposed by the longer wait at the bulk of the stations. If it were possible to reduce headways drastically, savings would improve. Headway, however, is dependent upon the traffic to be served on this line, and its relation to the traffic feeding the subway from the other branches. Another factor which reduces the effectiveness of skip-stop is that station spacing is already fairly long compared with other systems using it.

It appears that the saving in passenger minutes does not justify reconstruction work to permit maximum speed through stations (pedestrian bridges, stairs, etc.), and that lower speeds through stations would produce little or no savings in passenger minutes. Thus, institution of a full skip-stop service cannot be recommended at this time. In the longer range if stations are rebuilt for other reasons, such as coordination with urban renewal as is proposed at Brookline Village, and/or additional rail capacity for downtown distribution is provided to allow a shortening of headways, a form of skip-stop service may be more practical.

The concept of limited stop service as is used in Cleveland and on the DRPA was also investigated for the Highland Branch. With this concept certain trains skip a number of adjacent stops on the inner end of the line then make all stops to the terminal. Other trains make all stops. The interval between trains must be great enough that the limited stop train does not catch up with the preceding local train.

In the example investigated, every other train would be a limited, bypassing all 4 stops between Reservoir and Fenway Park. With this pattern, all trains originated at Riverside and the passenger load was split almost evenly between the limiteds and the locals. To do this, a limited would leave Riverside, followed 3 minutes later by a local, which was followed 6 minutes later by the next limited. Thus, more passengers would accumulate for the limited, and the limited would have enough time to run fast east of Reservoir, arriving at Fenway Park about 3 minutes after the preceding local. Thus, 3 minutes running time was saved. Unfortunately, the passengers using the limited have a longer wait, as do those boarding the locals at the stations east of Reservoir, than they would have if they used normal evenly spaced local service. The run time saving of 3 minutes generated a passenger minute saving of only 4.5%. Like skip-stop, this kind of operation might be more applicable in a longer range program.

Once new cars and facilities are in use there may be changes in traffic demand, and operating capabilities which are difficult to predict now. These may open up the possibility to incorporate a skip-stop or limited stop service for a few selected trains in the peak periods rather than service with many limited trains over a duration of several hours, as was tested in the examples above.

C. REDUCE DURATION OF STOPS

The length of time spent by trains standing at stations loading and unloading, "dwell time," is a problem with the present system. It affects overall travel time as well as line capacity.

In the case of the upgraded Highland Branch, a dwell time of 20 seconds will be about 1/3 of the total time spent braking, loading and accelerating back to full speed of 55 to 60 mph. On the surface reservation lines, a 15 second dwell time is about 1/2 of the time needed to stop and start when the maximum speed is 35 to 40 mph, assuming no additional time is added for traffic signal delays.

In the subway, where considerably larger volumes of traffic must be handled, present average dwell times of 30 to 35 seconds are just under 2/3 of the time needed to stop and start with the same maximum speed of 35 to 40 mph. When a Green Line route such as Beacon Street is taken as a whole, approximately 28% of its present one-way A.M. peak hour run time from Cleveland Circle to Park Street is spent standing to load or discharge passengers. About 8% of its run time is spent waiting for traffic signals. Thus, the total time savings which can be made by improvement of dwell time is limited. Reduction of dwell time at all stops by 25%, if possible, would reduce the run time from Cleveland Circle to Park Street by approximately 7%.

Dwell time is basically a function of the amount of people to be handled and the physical characteristics of the path these people must follow between platform and train. As pointed out above, the Green Line system is moving a lot of people, and in the case of the downtown stations, the only way substantial reductions of passenger volume can occur is by construction of other major transit facilities.

Taking the present traffic, plus predicted future growth as given, it is up to the Authority to reduce the friction which affects the flow of people on and off the cars. These changes will occur primarily in the areas of: car design, stations, fare collection procedure (surface lines only), and system routing.

1) <u>Rolling Stock Improvements</u>

The worst problems with dwell time in the Green Line subway occur at stations where trains must load from the left side. The present PCC cars have a single 2-lane door on the left side and two 2-lane doors on the right. The problem is particularly acute at the major stations where there is heavy transfer traffic to other rapid transit lines--Park Street and Government Center. Fortunately, Park Street has two tracks in each direction permitting some right-hand loading, but the heavier traffic must be handled with left-hand loading. In addition, Park Street must handle up to 3-1/2 times the amount of traffic that the next heaviest station on the line (Arlington) must handle when transferring passengers are taken

into account. At Government Center all trains are faced with left-hand loading, and with today's cars and routings, each car door must handle roughly twice the traffic handled at Arlington.

The No. 6 car design has two 2-lane doors on each side. A 6-door configuration was considered but it resulted in an excessive loss of seating capacity, and a serious conflict with the placement of air conditioning and other electrical equipment under the car floor. The use of an articulated design would make possible more doors for a given length of car.

The estimated capacity of these doors will be at least 60 persons per minute per door, giving a total of 120 persons per minute for one side of the car. This is based upon studies of existing PCC cars which have slightly higher flows for center doors, and lower for end doors. The differences in the PCC cars are due to the configuration of steps, hand rails, and fare box location which inhibits flow at the end doors. The No. 6 specifications are designed to eliminate this restriction and permit a flow rate of 60 per minute, per door for typical conditions of mixed boarding and alighting in the subway.

Experience with the PCC cars indicate that flow rates when all passengers are boarding (with none alighting) is roughly 15% higher, while a one-way flow of passengers alighting exclusively is only slightly higher than the two-way flow situation. This difference appears to result from the ability of persons waiting on a platform to form a group which can meld into 2 lanes of traffic from many directions with a minimum of physical restraints on the platform. On the other hand, persons on the car waiting to alight are restrained into longer queues by the aisle and stanchion configurations. The Type 6 car with doors on opposite sides of the car directly opposite one another will have a vestibule or reservoir area at each door larger than those available in the PCC cars. Thus, there it will be possible for larger numbers of persons to group near the door as the train approaches stations with heavy alighting traffic. This should raise the flow rate for one-way alightment traffic to approach that of one-way boarding traffic, or roughly 70 persons per minute per door when all or most are either boarding or alighting.

The presence of steps is a known restraint on passenger flow rates. A number of studies have been made to determine the feasibility of reducing the number of steps, or eliminating them entirely. As discussed elsewhere in the report the option of raising platforms to car floor height requires a radical reconfiguration of the Green Line network which would be extremely expensive to accomplish, and could result in reductions in the quality of service to large volumes of riders. Raising platforms in the subway stations would

require reconstruction of escalators, and certain stairways, in addition to raising the platforms, which is costly and impossible to do without complete replacement of the car fleet. Raising platforms on the surface reservations is impossible in many areas due to the narrow width available, so that reconstruction of the streets could be necessary in order to provide enough width of platform to be safe and psychologically comfortable, as well as space for a narrow left hand shoulder for the street traffic. To do this in some areas, stops would have to be eliminated entirely. The phasing of a changeover period would be extremely difficult at both subway and surface stops.

A compromise solution calling for medium height platforms, possibly 18 to 24 inches above the track (with a car floor height of 32 inches) requiring one step in the car, has been investigated. As part of this effort, study was made of various schemes for cars with moveable steps, as are being used in several European cities to permit use of raised platforms on only part of the system. The lower platforms still have many of the problems and costs of the higher platforms, although if used on the reservations would be more easy to do and more acceptable to pedestrian and auto traffic than the full height platforms. Phasing of platform changes with the moveable step configuration would be far easier than a change to full height platforms. It appears that it would be desirable to specify car design to permit the addition of the moveable step feature in the future, if traffic demand justifies further increase in speed and capacity.

In order to obtain some of the advantages of the medium or high platform configuration without the problems, the No. 6 car was designed to provide a lower vestibule height. This means people can board the car with two steps, and travel a short distance before climbing one additional step into the car body. The present PCC cars require a climb of 3 steps all at once. The elimination of one step should speed boarding and alighting, as well as making it physically easier for older persons. It is estimated that reducing the steps to climb by one-third would add at least 10% to the flow rate of the doors, with a corresponding drop in station dwell time. Also, elimination of one step in each step-well adds some space for standees.

As a result of the improvements in car design alone, the dwell time at stations with right-hand loading only should be reduced approximately 10% to 15% with the No. 6 design, and considerably better with an articulated European design. At the stations with left-hand loadings, where dwell time is most serious, trains using the westbound outside track at Park Street (Riverside and Beacon Lines)

should have less than half the present dwell time, those at Park Street on the northbound track (toward Government Center) where loading is possible on both sides should have dwell time reduced by one-quarter to one-third. At Government Center, dwell time would be reduced by over one-half. The same applies to Haymarket and to the outside tracks at Kenmore, although traffic and dwell time are smaller. The improvements in vehicle design should result in total savings in dwell time for stations in the subway from Kenmore to North Station in the peak hours of 25% to 30%, or 1-1/4 to 1-1/2 minutes of travel time. On the surface lines, reductions will be less substantial due to the effects of fare collection delays.

2) Station Improvements

Station improvements for the purpose of reducing dwell time are extremely limited in first stage program. The biggest inhibitions to smooth flow of traffic on station platforms occur at Park Street Station, particularly in the westbound direction. The current station modernization program will rearrange the fare collection area on this platform to eliminate congestion at that point. It is recommended that the concession areas be redesigned to reduce conflicts between waiting and moving passengers and those using concessions. As part of redesign, the flower and fruit shop should be eliminated or reduced to less than half its present size. Trouble spots at other stations have been relieved by the station modernization work now complete.

Although the Phase I Immediate Action Program retains the basic low platform concept, there are some alterations which could be made to permit some improvement in dwell time, and passenger convenience. In the subway the platforms are 4 to 5 inches above the top of rail so that the step from platform to the first step in the car is more or less equal in height to the other steps in the car, approximately 9 inches each. On the surface reservations and at some stations on the Highland Branch, platforms are usually at rail level. Although this extra step height does not bother the average person, it is an inconvenience to elderly or handicapped persons. It is recommended that, in conjunction with regular maintenance programs, the loading platforms be resurfaced and raised 4 to 5 inches.

One source of delays in loading downtown is the lack of clarity as to train destination, which is always a problem with multi-branch systems. The destination signs on the trains are not really adequate. As a result, those who are uncertain of the destination of a particular train can delay the others who want to board or alight.

It is proposed that automatic destination signs be installed at major loading areas in the subway to give advance notice to waiting

passengers of the train's destination. Thus, those not wanting a particular train can stand back and keep the way clear for those who do. This equipment, which will be installed in conjunction with the signal and communications work, will be actuated by the automatic train identification system, and will give notice of a train about one minute in advance of its arrival. The signs will be arranged to permit berthing of two trains at a platform the same time. At stations, such as Park Street where trains now stop at fixed location for each route, the destination would be permanently displayed with the variable destination feature used only when changes from the normal route are desired.

The savings in dwell time gained by limited station improvements will contribute to reduced travel time, but in addition they will help system reliability and regularity by helping reduce some of the more extreme variations from the average dwell times.

3) Fare Collection Procedures

One of the significant contributors to dwell time on the surface stops is the fare collection process. When riders have the exact fare there is little delay in the boarding process, but when change is required the boarding time per passenger is greatly increased, especially as fares become higher and require odd combinations of coins.

The institution of the exact fare system, now planned by the Authority, will eliminate time losses due to change making. On the Highland Branch a sampling of peak period running times indicated average stop times in the peak direction of travel of 22" in the A.M. peak hour and 15" in the P.M. A more detailed speed and delay survey of the Beacon Street Line indicated average stop times of 24" in the A.M. and 27" in the P.M. However, in the case of the Beacon Street Line the time spent waiting for traffic signals amounted to approximately 40% of the total stop time, leaving average stop times for boarding or alighting of approximately 18". It is estimated that elimination of change making by use of the exact fare plan would reduce boarding time by a maximum of 25%, and alighting time somewhat less as passengers can obtain change when they enter the subway stations downtown. This amounts to a maximum of one minute average saving on the surface portions of the Beacon Street and Huntington Lines, one and one-half minutes on the Commonwealth Line, and one minute on the Highland Branch. Although small, these savings when added to those resulting from other improvements allow more substantial reductions in total travel time and contribute to more reliable and regular service.

The possibility of instituting prepayment of fares at busier stops or stations on the surface branches has been investigated.

It is difficult to provide prepayment facilities at stops on the surface reservations except at a few locations such as Coolidge Corner and St. Mary's on Beacon Street. Even at these locations it is not possible to provide physical enclosures that would have as good security as is found at rapid transit stations. Unfortunately the better the security, the less convenient it is to the public, and the more damage it does to the street scene. It appears that the disadvantages outweigh the advantages, particularly when operating costs are considered, so that prepayment at any surface locations on the reservation routes is not recommended.

On the Highland Branch it is more feasible from a physical design standpoint to provide prepayment facilities, if justified by traffic. The average of the boardings at the four heaviest stations on the Highland Branch (Riverside, Newton Center, Brookline Village, Fenway Park) of 2,100 exceeds volumes at 7 rapid transit stations elsewhere on the MBTA. This is not to say that station fare collection is practical from an economic standpoint at this volume. The maximum saving in dwell time at the heavier stations on the Highland Branch that might be possible with prepayment might amount to little more than one minute in round trip time. This is not enough to make up for the operating cost of part time fare collection at stations. The savings would be even less significant after the exact fare system goes into effect.

Although not recommended in this phase, the possibility for installation of prepayment facilities should be left open for the future. Radical changes in land use at a particular station could justify part or even full time prepayment. Preliminary design studies of modifications to Brookline Village Station, done in conjunction with urban renewal work, have kept this option open.

D. REDUCE UNNECESSARY WAITING DUE TO CONGESTION AT JUNCTIONS AND INTERSECTIONS

Today, a certain portion of every rush hour journey on the Green Line is spent standing still for purposes other than loading or unloading passengers. Some of this time is lost in queuing when one train must wait for a train ahead to load or unload, and can be reduced by the dwell time improvements discussed above. The balance of the unproductive standing time is spent at junctions in the subway and at street intersections on the surface.

1) Subway Junctions

The present Green Line subway has seven junctions used by regular service (this includes the junction at Haymarket for the Canal

Street loop). Five of these involve simple diverging and converging moves (Kenmore, Boylston, Park, Government Center and Haymarket), and two (Beacon Junction and Copley Junction), involve diverging and converging moves, plus the at-grade crossing of tracks carrying traffic in opposite directions. The location with the most serious delay and capacity problems is Copley Junction.

Time loss at Copley Junction results from waiting for other trains to converge with or cross another track, and from speed restrictions through the junction. Today in a typical rush hour, the critical portion of the junction which carries the inbound converging moves and outbound crossing moves is occupied by trains nearly 45% of the hour. This leaves very little time between trains, resulting in queue formation at the approaches to the junction.

A major improvement in operation of the junction would result from automatic control of trains as they approach the junction so that inbound and outbound trains on the same branch will meet at the junction. It is estimated that waiting time at the junction could be reduced nearly 30% if all trains using the Huntington branch met at the junction, with half that saving if only half the trains meet, assuming capacity is held constant.

Additional time savings can accrue from improving the speed of trains through the junction. Alterations to the track and signal system could double the speed through the junction of outbound trains on the Huntington branch, and increase the speed of outbound trains toward Auditorium and Kenmore of 1/4 to 1/3.

The other junctions create only minor delay problems. Installation of automatic traffic control at these points will cut down on delay time. As in the case with Copley Junction the time saved in expediting train movements through the junction can be applied to reduce travel time only, to increase capacity only, or held in reserve to allow more time to adjust for irregularities. In reality the improvement of junction capability should be split between these areas. With the schedule contemplated for the Green Line using new cars, approximately 15 to 30 seconds saving for each peak hour trip should be possible at Copley Junction, with smaller savings totalling the same amount for the other junctions.

2) <u>Surface Street Intersections</u>

The Bruce Campbell Speed and Delay Study of the Beacon Street reservation line indicated that on the run from Kenmore to Cleveland Circle about 10% of the peak hour run time is spent waiting at traffic signals. In the A.M. peak, for example, inbound trains have a total average waiting time at traffic signals of 1'35", with an average wait at each signalized intersection of nearly 15".

The wait times are 30% higher for the P.M. peak outbound trains. Some additional time is spent waiting for traffic at unsignalized crossings, although delays at these points are random occurrences and normally of short duration. These are not as frustrating to the pasengers on the train as a long red light, particularly if it occurs at a stop where there is considerable boarding or alighting activity, resulting in a total stop time of over a minute.

The most troublesome area on the Beacon Line is in the vicinity of Coolidge Corner. The consultants developed several alternative schemes which moved the loading platforms at Harvard Street to the far side of the intersection (the train crosses the intersection before stopping for passengers) rather than the near side of the intersection (the train stops to load before crossing the intersection). The advantage of this scheme would be that trains could fit into the movement pattern of the progressive traffic signal system and avoid long waits for traffic signals at Coolidge Corner. This would save over 1/2 minute for every peak period train through this point. In addition, more capacity would be provided for street traffic at this and adjacent street intersections.

The consultant recommends changes in traffic signal phasing and provision of left turn lanes at a number of intersections, as well as prohibition of left turns or elimination of track crossings at several points, which will ease the flow of street traffic and eliminate some train-auto conflicts and delays. Extension of progressive traffic signal system could lead to possible further savings in travel time for the trains.

The Authority staff study of the inner end of the Huntington Avenue line, done in conjunction with the Boston Redevelopment Authority, has indicated that widening the median, closing of several street crossings, and channelization of street traffic, should provide a smoother, safer flow of both trains and automobiles. It is estimated that at least 1/2 minute run time will be saved by each peak period train on the run between a terminal near the intersection of Huntington and South Huntington, and the portal.

The Commonwealth Avenue Line has not been studied in the same depth as Beacon Street, but preliminary examination of the line has shown that many of the improvements suggested for Beacon Street could be applied to Commonwealth, once they have been tested initially on Beacon.

Trains on the Commonwealth Avenue Line are subject to considerable delay at Warren Street where the transition is made by the tracks from the normal median strip location to a location between roadways and the service roadway lying along the north side of the Avenue.

This off-center location exists between Warren Street and Packard's Corner (Commonwealth and Brighton) where a return is made to a normal median. The ultimate solution to this problem at Warren Street, which will also result in a smoother operation at Packard's Corner, would be to relocate the tracks in this 4,500' stretch of line to a normal median location--trading places with the present westbound roadway. This would be similar in scope to the work recently completed between Chestnut Hill Avenue and the Lake Street terminal. As both the roadway and trackage from Warren Street to Packard's Corner are in reasonable condition, it is not recommended to rebuild this section as part of the immediate action program, but the possibility should be left open for the future.

New traffic channelization, and possibly the closing of one or two minor crossings, is possible and should be investigated jointly with the City. Any steps to help move street traffic, if properly coordinated with the transit facility, can help reduce delays to the trains and permit some reduction in run time.

One idea which was studied for Beacon Street but rejected was the preemption of traffic signals by the trains. On Beacon, such a system would not fit in well with the progressive signal system as now set up and offered little time saving to the trains. On Commonwealth Avenue, however, there are some conditions somewhat different than on Beacon, particularly east of Packard's Corner. In this stretch there is more activity on the south side of the avenue than on the north. As a result there are many locations where left turns are possible from the westbound roadway, with most of them requiring a special signal phase which can delay the trains. As turning traffic is not heavy at any one of these points, and there is plenty of width for westbound traffic, it should be possible to allow the trains to preempt the signals at most of these crossings. It would also be possible to give automobiles more time to cross when there are no trains approaching. With the present system, both cars and trains must often wait at a red light for non-existent traffic to make a crossing move.

It is estimated that traffic improvements along the Commonwealth Avenue Line, assuming tracks remain largely at their present location, could reduce scheduled run times for each train in the peak hours by at least 3/4 minute, as well as reducing abnormal delays to trains and automobiles.

E. SUMMARY OF TOTAL BENEFITS

This section has covered the various means of reducing travel time from origin station to destination station. The basic approaches to reducing travel time include: Increase running speed, reduce number of stops, reduce dwell time, and reduce waiting time at street crossings or subway junctions. The means employed to achieve time savings include: new cars, improved track, new signal system, upgraded power supply, elimination or modification of stops and stations, street traffic improvements, and changes in fare collection procedure.

Table 10-1, "Summary of Time Savings Resulting from CASS Immediate Action Program," indicates the benefits which would result from implementation of the various improvements described in this section. It is important to note that the total time savings shown in Column 5 are possible only if the entire program is carried out.

A range in savings has been indicated for "Reduced Number of Stops" (Column 2), and "Reduced Wait at Crossings" (Column 4), to allow for alternative schemes for stop consolidation and street traffic control. A range in savings resulting from "Increased Running Speed" (Column 1), and "Present Total Run Times"(Column 6) results from differences in performance for new cars vs. the present cars in the inbound and outbound directions. (The present cars are slowed down considerably going upgrade in the outbound direction, while the new cars will be less affected by the grades.) The times shown on the table represent peak period, peak direction operation, i.e., the lower number in Column 6 represents the morning peak period inbound direction, and the higher number the afternoon peak period outbound direction.

It should be noted that the time savings quoted in the table are based on estimated performance of the new cars on the various line segments. The main benefits of the new cars are the savings from increased running speed, and reduced dwell time, although only part of the dwell time savings on the surface branches results from car design and part from the assumed exact fare operation.

Present off-peak run times for trips from the branches through the subway for Highland Branch trains are 10% to 15% less than in the peak periods, and on the reservation routes 15% to 20% less. The differences between peak and off-peak result from decreased passenger loadings which effect stop time and running speed, and decreased congestion in the subway and on the surface reservations. It is expected that more or less the same relationships would hold in the future with the immediate action program in full effect.

Table 10-1

SUMMARY OF TIME SAVINGS RESULTING FROM CASS IMMEDIATE ACTION PROGRAM

(In Minutes)

	Time Savings Resulting From:							
Line Segment	(1) Increased Running Speed	(2) Reduced No. of Stops	(3) Reduced Dwell Time	(4) Reduced Wait At Crossings	(5) Total Time Savings	(6) Present Total Run Times	(7) Future Total Run Time	(8) % Saving
Highland Branch Riverside-Kenmore	7 to 8-1/2	-	1/2 to 1	-	7-1/2 to 9-1/2	29 to 33	21-1/2 to 23-1/2	26-29%
Beacon Street Cleveland Circle-Kenmore	1/2	1 to 1-1/2	1	1/2	3 to 3-1/2	16 to 19	13 to 15-1/2	19%
Commonwealth Ave. Boston College-Kenmore	1/2 to 3/4	1 to 1-1/2	1-1/2	3/4	3-3/4 to 4-1/2	25 to 28	21-1/4 to 23-1/2	15%
Subway Kenmore-Park	1/2	-	3/4	1/4 to 1/2	1-1/2 to 1-3/4	9 to 10	7-1/2 to 8-1/4	17%
Huntington Avenue Hunt. & S.Hunt.-Park	1/2	1 to 1-1/2	1	1/4 to 1/2	2-3/4 to 3-1/2	17 to 18	14-1/4 to 14-1/2	16-19%
Subway & Elevated Lechmere-Park	1/2	-	3/4	1/4	1-1/2	10 to 11	8-1/2 to 9-1/2	14-15%

Note: Time savings and run times are for peak period, peak direction flows.

The time savings shown on the table are somewhat on the conservative side, assuming the entire program is carried out. This allows allocation of some of the possible time saving to improvement in system reliability and regularity, which is described more fully in Section II.

II. IMPROVE RELIABILITY OF SERVICE

INTRODUCTION

One of the most severe problems with the present Green Line system is the poor reliability of the service. Today, the rider has little confidence in the ability of the system to deliver him to his destination at a predictable time. Failures of equipment are all too frequent, particularly in the peak hours and during periods of inclement weather.

There are two basic approaches which can be taken to improve system reliability. First is to eliminate possible sources of delay, i.e., reduce the frequency of delays, and second, reduce the duration of delays when they do occur. Implementation of improvements which follow both approaches to the problem will benefit the rider on the train and the prospective rider waiting for the trains.

Improvements in reliability will reduce the total amount of time which riders now using the system must allow for reaching their destination, as well as raising the general public's confidence in the service which would help regain riders who have been lost in the past.

The kinds of improvements that will eliminate delays include purchase of new cars to replace a fleet of overaged vehicles, and improvements to the infrastructure such as replacing worn out track and antiquated signal systems. This report must stress again the importance of purchasing a full fleet of vehicles if the reliability standards are to be achieved.

Methods for reducing duration of delays include such things as installation of train radio system and provision of additional crossover tracks which would permit the bypassing of areas where trouble exists.

A. REDUCE FREQUENCY OF DELAYS

Ideally we would like to eliminate all delay-creating situations in the Green Line system. A more realistic goal is to vastly reduce the number of delays and seriousness of such incidents.

Deviations from schedules may affect the internal operation of the system (layover time, lunch breaks for operators, etc.) but may not adversely affect the passenger if all the trains to a particular destination are more or less uniformly delayed. The rider does not care whether a particular train is running to schedule as long as his waiting time and riding time are not excessive.

The effort of the Immediate Action Program is directed toward making improvements which will reduce the incidence of the less frequent serious delay situations which stop service completely, and those which occur much more frequently but, taken individually, have less impact on waiting and riding times. The former include such things as power failures or derailments, and the latter, conflicts at street intersections or congestion at stations.

1) <u>Reduce Failures of Rolling Stock and Facilities</u>

The major cause of the more serious delays is failure of rolling stock and facilities. Failure of trains in service creates most annoying delays, but delays may also be created by shortages of cars caused by previous failures in car equipment.

a) Rolling Stock Failures:

A study made in 1966 which summarized in-service failures on the Green Line system for the month of January indicated that there were a total of 214 incidents which caused a total delay to service of 26 hours 54 minutes, or an average of 7.5 minutes delay per incident. Failures of rolling stock amounted to 88% of all incidents and 78% of total delay time, with the average delay time per vehicle failure of 6.7 minutes.

A more detailed analysis made by Gibbs & Hill, Inc. of rolling stock failures made in 1966-1967 disclosed that for a seven-month period from August to March, there were 3.42 delay-causing troubles per car in the active fleet of 290 cars.

The principal conclusion which can be drawn from these studies is that the PCC car fleet as a whole is at the end of its useful service life. With the exception of a particular sub-group of the newest cars, the number of troubles increases with age. The apparent reason for the problems of the group of newer cars is that they are subject to very rigorous duty on the Highland Branch, a type of service for which they were not originally designed. In addition, being newer, they are running more miles per day than cars on other lines.

The standard of maintenance work over the years is not what the department responsible for this work would like it to be. The basic reasons for this is that during the many years when money was not available for transit improvements, and ridership was rapidly declining, sufficient money was not made available for maintenance work, or for proper facilities and equipment to do this work. The deferred maintenance is now taking its toll.

Availability of parts is also a problem, particularly for the older cars. Pressures to reduce inventories have also caused car shortages in rush hours due to lack of parts on hand.

Replacement of the present fleet with new cars should lead to a vast improvement in system reliability. In addition to the basic advantage of being new, the cars would have the benefit of being custom designed for the service, unlike the standard PCC car. With a motor horsepower 1.8 times that of the present cars, there will be considerable reserve capacity that does not exist today. The motor is also designed for the higher speed (55 mph) desired for the Highland Branch where the PCC cars have been strained severely in maintaining a considerably lower speed (38 mph).

Reliability of the new fleet will be enhanced by maintenance procedures which rely on parts which are continuously supplied by a manufacturer who builds light rail vehicles on a regular basis. This is in marked contrast to the present practice of manufacturing or cannibalizing component parts which are no longer commercially available.

It will be necessary, however, to adequately test the new cars prior to acceptance. A number of rail systems have run into serious difficulties in introducing new cars prematurely. More rigid requirements for testing and reliability should be written into the final specification.

An additional means of improving reliability through reduction in service failures will be provision of modern shop facilities for the Green Line. The Stage 1 program includes construction of a new car shop at Riverside, making it unnecessary to move cars by trailer truck to Everett Shops for major repair. The program also includes improvements to the Reservoir Car House.

b) Track, Roadway and Structures

Actual failures in these areas which cause serious delays to service are relatively rare. In the January 1966 study only 12% of all failures were for all categories other than rolling stock. One more typical problem is spreading of rails on hot days. The track work improvements which include replacement of overage ties, reballasting, and application of rail anchors will drastically

reduce these incidents. Replacement of special work (switches and crossings) at critical areas will eliminate another source of trouble.

The tightening up of maintenance standards, with more attention to a cyclical program for preventative maintenance will reduce the number of failures. Special work and short curves in the subway and in yards will need more attention. New criteria for maintenance of track and roadway, taking into account desired speed and projected traffic loads, should be established.

c) Signals, Communication and Power

The existing signal equipment has been in service on this line for a great number of years. Much of the apparatus presently used is in need of replacement and it is difficult to maintain as some of it is obsolete and no longer manufactured. This proves to be a real handicap when repairs are required as delivery of spare parts, if at all available for this type of apparatus, is a lot longer than standard items.

In order to keep the line operating, it is often required that temporary repairs are made until the proper parts are received; this of course results in excessive repair costs.

The switch machines for the interlockings and turnouts in the tunnel area are of the pneumatic type which requires that compressed air be piped to these locations. The compressors for these interlockings are old and antiquated and would have to be replaced in the near future. Compressed air operation is especially troublesome and unreliable during cold weather, below freezing temperatures. Thus, it is recommended that all switch machines be electrically operated.

The reliability of the signal system will be improved greatly by the installation of a new automatic train stop and speed limiting signal system. The components of the new signal system will be made up from reliable solid-state devices and present day standard signal equipment. This, together with a good preventative maintenance program will provide us with good service and reliability and a minimum amount of equipment failure for many years.

The addition of three new substations at Riverside, Chestnut Hill and Fenway will result in a major improvement in power system reliability. As the substations are tied into the present feeder network by a number of alternate paths, it will be possible to

compensate for and bypass disruptions in the older substations, or feeders. Centralized monitoring and control of the new substations, which will be an extension of the present supervisory system, will permit instant reaction to power system irregularities.

Improvement of the overhead trolley system will reduce the incidence of dewirements which damage cars and overhead and cause delays to service. Particular attention will be given to chronic dewirement problems at over-bridges and at sharp curves and special work in the subway. Development and installation of a more elastic suspension system for the trolley wire at these areas will permit higher speeds without dewirement by providing a smoother path for the trolley.

2) <u>Reduce Random Conflict with Operations</u>

After equipment and infrastructure failures, the other major sources of irregular operation and abnormal delays to riders are conflicts between one train and another in the subway, and between trains and motor vehicles or pedestrians on the surface lines. A number of the methods of alleviating these problems have been discussed in connection with the means for improving travel time, in the preceding chapter, where it was pointed out that time saving from certain improvements can be applied to reducing overall travel time and/or to the provision of additional recovery time to regularize operations.

a) Reduction of Internal Conflicts

Today's operation permits trains to approach and enter interlockings and the common tunnel area on a "go-when-you-come" basis. This of course results in a bunching of trains and slow irregular service. Once these trains are bunched, they usually stay that way until they reach the terminal. There are presently no means of allowing intermediate rescheduling.

One of the most important roles the new signal system must play is to provide proper rescheduling of trains upon entering the common tunnel area. The logic circuitry for these joining interlockings will be set up in such a manner that no train will be permitted into this common tunnel area unless there is room for it to merge properly with the other trains. This approach will provide a more uniform spacing and arrival of trains at stations. Therefore, each train will pick up its share of passengers, which will assist in reducing dwell time and alleviate congestion at stations and terminals. This, in turn, will permit a reduction in random delays and result in a more uniform pattern of operation as seen and felt by the consumer.

b) Reduction of External Conflicts

The surface reservation operation is subject to disruptions by other traffic. Shorter delays (under two minutes) at street intersections can be reduced in frequency and duration by stop relocation, traffic channelization, and traffic signalling, as has been described in the section on travel time improvement. Longer delays, such as those caused by accidents, can be more frustrating to the rider by disrupting service on the surface and in the subway as well.

The improvements in traffic signallization and intersection design will do much to reduce accident hazards and resulting delays. Provision of barrier curbs at areas where right-angle parking is allowed adjacent to the reservation will eliminate delays caused by autos infringing upon the rail right-of-way. Fencing to provide pedestrian control will also eliminate delays due to accidents.

Winter operation is more subject to disruption when automobiles become stuck on grade crossings of the reservation. It is recommended that more attention be given to snow removal and sanding of these points, and that arrangements be made for removal of stalled vehicles, utilizing a tow truck operated by the Authority or by contracting with a private firm. An alternative to using tow trucks would be to replace Authority inspectors' radio cars with vehicles suitable for pushing autos off the tracks.

B. REDUCE THE DURATION OF DELAYS

As it is impossible to eliminate all delay-producing incidents, attention must be given to means of reducing the duration of the delays that do occur. The delay is made up of several components, each of which may take varying amounts of time. Included are: notification that a problem exists, travel to the site of the problem, correction of the problem, and restoration of service.

1) <u>Provide New Means of Dectecting Delays</u>

Lack of good communications affects both the time required to notify the proper authorities of a problem and greatly hampers restoration of normal service. With certain kinds of incidents, improved communications may also reduce the actual time required in correcting the fault.

Present monitoring of train movements and communication with operators on the Riverside Line is quite limited, and on the feeder lines into the tunnel area, almost non-existing. This limited monitoring and communication with the train crews makes it virtually impossible to sense and act upon delay situations.

The entire Green Line system will be equipped with a train radio system. Equipment permanently mounted to present cars should be minimized and should be designed to permit reuse in new cars as older cars are retired. Starters and inspectors at strategic locations, as well as maintenance or emergency crews, should also be supplied with "walkie talkie" radio equipment.

The main advantages of train radios are reduction in time required to report troubles, ability to get advice directly without delay, and improved capability in keeping service going or restoring normal service by redirecting trains by direct word from dispatcher to train crew. The communications system should include loud-speakers within the cars so that passengers may be notified of delays and changes in service--offering a big improvement in passenger morale.

Permanent installation of a public address system should be made in stations now undergoing modernization. Temporary installations (which would include hardware useable after modernization) in stations not scheduled for immediate modernization should be made. The dispatcher should be able to call all stations at once, or selected stations, to make announcements to personnel and the public, about delays or changes in service.

It is proposed to install monitor devices to display key areas to the central dispatcher at Dewey Square control center. The system will include an ACI (Automatic Car Identification) system with an optical scanner like that on the South Shore extension, with provision for identifying car number, destination, and possibly the train or block number. The scanners or detectors will be spotted at closer intervals in the subway than on the branches. The system can be used for operation of junctions, as well as for traffic control.

With the aid of the key point monitors and the two-way radio system, it will be possible for the dispatcher to observe the performance of the various legs of the Green Line and to take remedial action when an unusual condition occurs.

Closed circuit TV has been considered within the Station Modernization Program as primarily a security or public safety measure. Certain of these installations, plus some at points outside of stations (at loops, yards, junctions, etc.) could serve as an additional aid, to the Green Line dispatcher in keeping track of congestion on the line and in stations.

2) <u>Provide New Means of Taking Corrective Action</u>

Improved communications giving instantaneous information about problems on the line are of little value if proper facilities to alleviate the problem are non-existent.

The design of the vehicle propulsion system has a major impact upon the minimization of emergency delays. With the present PCC vehicle, a failure of any one of the four driving motors cuts out all motors on that car. Modern light rail vehicles presently in European operation employ a mechanism which allows one of the two traction motors to propel the vehicle in emergencies.

Often it is not possible to correct equipment failures on the line, so the offending vehicles must be removed from traffic as quickly as possible. At the time when surface operations were more extensive, many loops, crossovers, and sidings were available as refuges for trains in trouble, and for modifying service by turning back trains, or by isolating the portion of the line in trouble without stopping up the whole network. Abandonments of surface trackage, such as the Braves Field loop, have seriously reduced system flexibility. There are a number of possible modifications to existing trackage which would improve operational flexibility within the subway and on the surface branches.

It is proposed to install single crossovers at three existing locations and double crossovers at four new locations on the Riverside Line. With the new signal system, it will be possible to use these crossovers as an intermediate turnback facility or to go into reverse running between two crossovers, bypassing the troubled area. Under reverse running conditions it will be possible to maintain a ten-minute headway to the end of the line while turning all other trains at one of these emergency turnback facilities. With these facilities, it will be possible to maintain proper headway through the downtown area and yet have limited service to the end of the line even though a breakdown or accident has one of the tracks blocked. Figure 10-3 shows the proposed location of these crossovers.

In the subway, it is proposed to add a single crossover at Arlington (in the opposite direction to that at Charles Street); on the Lechmere Line one additional crossover at Lechmere and one at Lowell Street; on the Beacon Line, a double crossover at St. Mary's; and on the Commonwealth Line, new single crossovers near Warren Street and Chestnut Hill Avenue, and replacement of an existing crossover at Packard's Corner.

The crossovers are made practical for emergency turnback operation by the use of cars with double-end capability. The new fleet may consist of a smaller group of cars with full double-end capability and a larger group of single-end cars normally coupled back-to-back. Loops will be maintained at all present locations for normal turning of cars, as the remaining existing cars are single-end.

HIGHLAND BRANCH - Proposed Crossovers

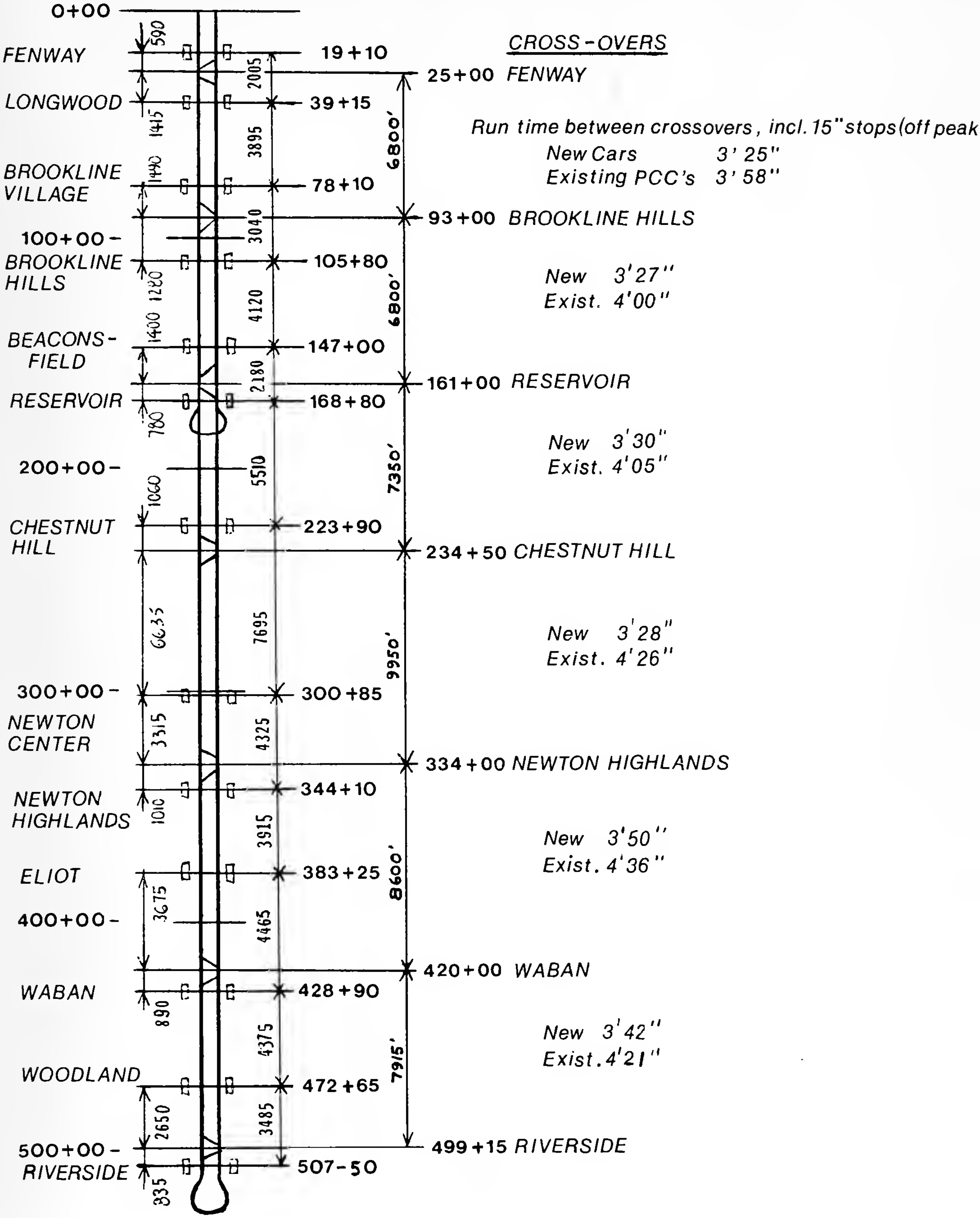


FIGURE-10·3

C. SUMMARY OF TOTAL BENEFITS

This section has described a number of factors which contribute to poor reliability of the present system, and has pointed out the methods proposed for improving it. The first problem is to reduce the frequency of delays, and this will be done by replacing worn out cars and infrastructure, along with provision of better facilities to maintain the new cars and facilities. The new equipment will be designed for the job it is to do, and by maximizing use of standard rapid transit components, it will be easier to maintain.

Random conflicts in operation, both in the subway and on the surface, will be reduced by improved signal and train control devices, and by new traffic control arrangements on the surface reservation routes. Elimination of accident hazards will vastly reduce the frequency of major delays.

The duration of delays will be reduced by providing new means of detecting irregularities, such as two-way radios on all cars, and an automatic vehicle monitoring system at selected points, all tied in to a central dispatcher.

The installation of new crossover tracks and provision of double-end operating capability for the new cars will greatly improve the flexibility of the operation. It will increase the opportunity to bypass trouble areas, and modify service so that a disturbance on one branch will have a minimal effect on the total system, and reduce the amount of time needed to put operations back in order.

III. IMPROVE PASSENGER AND COMMUNITY ENVIRONMENT

INTRODUCTION

This section will discuss the environment of the passenger while riding on the train and waiting in the stations, as well as the environment created by the trains and facilities as it affects those living or working adjacent to the line. The major issues concern first, the quality of ride, temperature, ventilation and humidity, noise level, and visual design, as experienced by riders on the trains; and second, noise levels and physical aspects of subway facilities and surface rights-of-way, as experienced by passengers in stations or persons along the line.

A. PASSENGER ENVIRONMENT

There is no denying that the present Green Line system, and the Highland Branch in particular, present a "Toonerville Trolley" image to the riding and non-riding public. Fortunately, there are a number of means available for changing this image. They involve the replacement of outmoded equipment or facilities, and general rehabilitation of others so that they may be brought up to and maintained at a level comparable to that of our new rapid transit extensions.

Today, the passenger is subject to rough rides, temperatures and humidity which are usually too high or too low for comfort, and high noise levels--particularly on the frequent sharp curves found in the subway. Technological breakthrough or huge capital expenditures are not required to solve these problems. Instead, the rigorous application of existing techniques and hardware or materials will be sufficient to make a major improvement in passenger environment.

1) Improve Ride Quality

The "Toonerville Trolley" image which is often applied to the Highland Branch is largely created by the very poor quality of ride. The track on the Highland Branch was only partially rebuilt when the line was acquired for transit use. The cars used on the line were never designed to operate at speed on this kind of track. In addition to the rough riding on surface track, all of the lines when they enter the subway are subject to stop-and-go operation brought about by congestion at junctions and stations.

Although the PCC car introduced the soft ride to rail transit, this feature unfortunately was attended by poor roll stability. Thus, in the new car design, attention has been focussed on improving the ride qualities.

In the No. 6 prototype, the trucks are of the inside-journal type, constructed of cast steel, possibly utilizing chevron rubber springs at the pedestals, with bolster springs of the "Pirelli" type, or a combination of pneumatic and helical steel springs. The use of pneumatic springing plus suitable shock absorbing devices will help create a level of riding comfort far above that of present cars under any condition of passenger loading. Improved braking and control systems will reduce the "jerk" associated with stopping and starting. Because of the acute restriction on space, the design of the trucks is severely restricted, and it is not possible to incorporate all of the ride control features which otherwise would have been specified.

A major contribution to improved ride will be upgrading of the track, which will include replacement of worn rail and ties, as well as the improvement of alignment and super-elevation (banking) on curves, will smooth out the ride and permit raising the top speed from the present 37 mph to 60 mph. It is important to note that, within the existing surface and subway roadbeds, considerable improvement can be made which would affect ride quality as well as maximum speed, without land takings or major structural changes. The use of heavier rail and welded joints, along with new ballast and drainage improvements, will make it easier to maintain a higher standard of track alignment and grade. It is recommended that the Authority set new standards for maintenance of track quality, which will be related to the speed and density of traffic on each line. In addition, the Authority should invest in new track maintenance equipment for use on all rapid transit lines to improve productivity and quality of work.

2) <u>Improve Ventilation, Temperature and Humidity Control</u>

Unlike their predecessors, the new cars will be equipped for air conditioning. To complement the air conditioning system, the side windows of the car will be grey tinted laminated safety sheet. Electric heaters will provide for the air conditioning humidity control reheat cycle, and will be used to furnish the total heat during the winter.

3) <u>Reduce Noise Levels</u>

It is intended that the interior noise level will be markedly less than on our PCC cars. To this end,the No. 6 calls for a variety of noise reduction measures which include fiber glass insulation in the sides, ends and roof, and a subfloor with a fiber glass insulation interposed between it and the main floor. The fiber glass will also serve to provide thermal insulation. The treatment will be similar to that used in the new South Shore cars.

The new ventilating system will also contribute to reduction in noise levels inside the car as it will be possible to operate with sealed windows, and to eliminate direct paths for noise transmission as now exist with the ventilating system on the PCC cars.

The application of sound absorbing treatment at sharp curves in the subway tunnel and stations will reduce noise levels experienced by riders on the trains. A portion of the sound energy which is now reflected into the car or transmitted directly through the air from a passing train on an adjacent track would be confined and absorbed by this treatment.

4) Improve Interior Layout and Finishes

The seating layout will consist of longitudinal and cross seats, arranged to ease circulation through the car, and provide a reasonable degree of passenger comfort. A two-car unit will provide for 90 seated and 174 standing passengers, for a total capacity of 264 persons. The seats will be upholstered with highly fire-resistant rubber or urethane foam covered with fabric-backed vinyl.

Interior finishes will consist of durable melamine-faced laminates, vinyl-coated aluminum, and integrally-colored ABS thermoplastics. Stainless steel will be used in areas subject to hard wear. Floors and steps will be of resiliant rubber materials.

We expect, as with our South Shore cars, to achieve a quantitative level of lighting of about 60 foot-candles on the car interior by means of two rows of fluorescent lights that are to be flush-mounted in the ceiling.

B. STATION AND RIGHT-OF-WAY ENVIRONMENT

The improvement of the physical environment of the stations is already well along, with the present station modernization program. This program, when its initial phase is complete, will have brought about complete modernization of Kenmore, Copley, Arlington, Government Center and Haymarket Stations. On the Blue Line, Bowdoin, Government Center, Aquarium, Maverick, Airport, and Orient Heights Stations will have been modernized. The minor modernization program, to be completed within the next year, will provide new graphics and information systems as well as extensive repainting of the balance of the stations. The Stage 2 program would provide further complete modernization of stations not covered in the present program.

The environmental issues yet to be covered include: noise level at sharp curves, in tunnels and stations, and along surface routes, and the visual aspects of surface rights-of-way.

One environmental problem of the city as a whole (air pollution) is not a problem of the Green Line system. In fact, the pollution levels along the Green Line routes will be partly held in check by retention and the improvement of the electric vehicle system. Unlike the other rapid transit lines which require feeder buses to provide much of the access between residential neighborhoods and stations, the Green Line provides most of its own collection and distribution with electric-powered vehicles.

1) <u>Reduce Noise Levels in Tunnels and Along the Right-of-Way</u>

On straight track the present cars, when in reasonable condition and with closed windows, are quieter than most of our older rapid transit cars. On tight curves, the PCC cars will squeal as do the rapid transit cars. It takes an extremely large increase in curve radius to eliminate wheel-squeal. It appears that one of the more effective means of reducing wheel-squeal, other than the improvements on the car, is to provide sound absorbing material at curves in the tunnels and stations. This would be utilized on present tunnel walls and on new barrier walls which could be erected at the worst problem areas. Recent tests in BART and with the Expo Express in Montreal have indicated that barriers lined with sound-absorbing material, along with sound-absorbing material on tunnel walls, can produce substantial decreases in noise. Tests have shown noise reductions of 10 to 12 db, which amounts to an apparent noise reduction of one-half.

Another approach to eliminating wheel-squeal utilizes water spray lubrication of track. Experiments with this are now underway and initial results show that squeal is eliminated entirely, and apparent noise level is cut in half. More research is needed to develop the system for winter use, and subway applications.

The community environmental problems are largely related to noise along certain sections of surface lines. The improved roadbed with welded rail joints, and elimination of rail corrugations which occur in certain areas, will do much for alleviating the noise problem. Certain of the techniques discussed in relation to the subway can also be applied outdoors as well, such as the sharp curves on the Lechmere elevated structure.

2) Improved Maintenance of Rights-of-Way and Facilities

The existing rights-of-way, particularly the reservation routes, are suffering from many years of deferred maintenance. The proposed track improvements on the Highland Branch will do much to spruce up its appearance, although it is also recommended that the Authority maintenance program replace fences which are in disrepair.

The proposed channelization and stop relocation work on the reservation routes, along with the installation of new fences and traffic barriers, will improve the appearance as well as operating characteristics of portions of these lines. The Huntington Avenue Line is scheduled to undergo reconstruction of the entire reservation. Remaining areas of the other lines should be upgraded in appearance in conjunction with routine rail raplacement program.

The cleaning of tunnel and surface rights-of-way and stations, maintenance of fences and drainage facilities, and vegetation control should be set up on a more rigidly controlled program than we have at present. To carry out these programs, the maintenance departments must be given the proper equipment to do the job.

C. SUMMARY OF TOTAL BENEFITS

The CASS Phase I program will result in significant improvement to the environment of riders on the trains and in stations, and for those who live or work in the neighborhood of the surface lines. The new cars will provide a standard of comfort comparable to that of modern rapid transit cars, such as those on the new South Shore extension.

Improvements to track and addition of noise reducing treatment at sharp curves, will contribute to the improved ride and reduced noise level in cars and stations. Institution of new maintenance programs, aided by increased mechanization, will help keep the condition of stations and rights-of-way at a higher standard.

IV. IMPROVE SAFETY AND SECURITY

INTRODUCTION

The existing Green Line system utilizes automatic block signals in the subway, on the Lechmere elevated, and on the Highland Branch. The reservation routes are not block signalled, although they are under the control of the street traffic signals at major intersections.

The present signal system does not provide the automatic train stop capability which prevents trains from running red signals, as is found on the three other rapid transit lines. As speeds are now limited to 40 mph or less, full manual control is feasible, and is considered safe. To maintain a reasonable degree of safety with the present operation, a number of severe speed restrictions and other procedures are required, which adds to travel time and annoys passengers with continuous stop-and-go operation through the subway.

As it is desired to increase travel speeds by easing speed restrictions and providing higher speed capability in the new cars, it is necessary to replace the existing signal system with one which will provide a higher level of safety, eliminating the chances for human errors which exist with the present equipment.

On the surface reservations there are a number of locations which are hazardous for pedestrians and vehicular traffic. In some cases there are conflicts between trains and pedestrians or autos, and at others there are hazards for pedestrians crossing streets on their way to or from the trains.

Improved methods of surveillance of trains and stations are needed to reduce incidence of crime and disturbance, and to speed the taking of corrective action when accidents or problems do occur.

A. PROVIDE AUTOMATIC TRAIN STOP CAPABILITY

The new signal system will provide automatic train stop capabilities. The proposed design calls for the following: the train will only be able to move as long as a cab signal command is present in the running rails. The instant the signal command ceases to exist in the rails, the train will come to a complete stop. Once stopped, it will not be able to proceed until a new signal command is received or the operator uses a close-in mode. This permits the train to proceed under the responsibility of the motorman at a speed not more than 10 mph or other safe speed yet to be determined.

The train will also be forced to stay within the safe speed limitations while traveling by means of the speed commands. These special commands permit the train to travel at only the maximum speed permissible for the section the train occupies. Upon entering a lesser speed area, the motorman will get an audible and visible indication instructing him of the new speed required. He then has approximately 2.5 seconds to react. If he does not commence to apply the proper brake application within the required 2.5 seconds, the carborne signal package will then automatically

stop the train and penalize the motorman with a complete stop. The new signal system will always keep trains separated at a minimum of braking distance plus a safety factor. Closing-in on stopped trains will only be possible in the close-in mode, with a top speed of approximately 10 mph. The system will prevent the new higher speed cars from exceeding the speed restrictions in the subway or on the surface routes.

B. IMPROVE SURVEILLANCE OF TRAINS AND STATIONS

Continuous communication and intermittent key point surveillance will be provided between all trains and the central dispatcher. These features will provide the dispatcher with the necessary tools to properly observe the performance of the line and to take action if an accident occurs. The ability for the motorman to contact the dispatcher in case of emergencies at all times through his two-way radio will speed assistance and help him in as short a time as possible.

The existence of train radio and at selected points closed-circuit TV, will act as a major deterrent to criminal activities on trains and in stations. The present station modernization program, and the Authority design standards on which it is based, call for redesign of station areas to eliminate blind pockets, and open up the view as a means of reducing opportunities for crimes. The color coding system and station lighting standards are intended to highlight hazardous areas, such as the platform edges and stairways. Ultimate extension of station modernization work, including installation of a complete closed-circuit TV and public address system, will eventually bring all stations on the Green Line up to a consistently high standard of safety and security.

C. REDUCE CONFLICTS WITH PEDESTRIANS AND AUTOMOBILES

An extensive study of operational characteristics and safety problems was made by Bruce Campbell & Associates of the Beacon Street Line. The problems and their solutions are typical of those encountered on the Commonwealth and Huntington Avenue reservations, so are summarized below to indicate the scope of improvements desired for all three routes.

Pedestrian safety improvements can be made by:

- Providing properly maintained, well illuminated passenger platforms

- Providing fencing to channelize pedestrian movement across tracks

- Installation of pedestrian signals and revision of existing traffic signal timing.

Automotive (including trains) safety improvements are proposed where conflicts exist. Presently, these conflicting areas are:

- At signalized intersections
- At unsignalized intersections
- At vehicular crossovers
- At midblock locations

1) <u>Improve Pedestrian Safety</u>

a) Pedestrian Signal Installations:

All surface passengers using the MBTA trains cross at least one of the heavily travelled legs of Beacon Street. At Harvard Street, Summit Avenue, Winchester Street, Fairbanks Street, Washington Street and Dean Road, pedestrian-vehicle conflicts are reduced by use of pedestrian and traffic control signals. The Carlton Street intersection is currently scheduled for signal modernization which includes the installation of pedestrian signals.

A number of pedestrian accidents have occurred along Beacon Street between St. Mary's Street and Cleveland Circle, many of these occurring during hours of darkness.

b) Median Fencing:

At present there are no continuous barriers to stop pedestrian movements across train tracks along Beacon Street. Short stretches of fencing are found at Tappan Street, Winthrop Road, Washington Street and Coolidge Corner which restrict passenger movement across Beacon Street to intersections.

Interviews with MBTA operators revealed pedestrian-train conflicts on the tracks affected MBTA operations. Analyses of accidents of the past two years substantiate this as 31 pedestrian-train accidents occurred along Beacon Street.

Installation of fencing between the tracks will eliminate midblock pedestrian conflicts. Fencing between tracks is strongly recommended for the length of Beacon Street between St. Mary's Street and Cleveland Circle, both for safety and for ease of operation. Installation of fences on Commonwealth Avenue between Blanford Street and Packard's Corner, completed in 1969, has significantly reduced pedestrian accidents.

Openings must be provided at all intersections where cross traffic is allowed, and at such other locations as may be deemed necessary for public convenience after consultation with city or town officials. Openings should be provided at St. Mary's Street and all other locations where existing pedestrian crossings are marked. To determine if pedestrian signals are warranted at these crossing locations, a screen line count should be taken of all pedestrians crossing the tracks along Beacon Street.

It is further recommended that high level illumination be provided at all median openings and the adjacent street section. Proper location of median openings with respect to passenger platforms will enable illumination to be provided there at minimal cost.

c) Elimination and Consolidation of Stops:

The elimination and consolidation of stops, discussed before, will reduce the number of areas where conflicts between pedestrians, vehicles, and trains may occur. Activity will be concentrated at locations were appropriate safety measures may be taken.

2) Improve Vehicular Safety

a) Vehicular Crossovers:

Eighteen vehicular crossovers exist in the Beacon Street median between St. Mary's Street and Cleveland Circle. Seven locations are signal-controlled, i.e., Carlton Street, Kent Street, St. Paul Street, Centre Street and Dean Road are signalized with a special left turn phase.

All left turns are prohibited to eastbound Beacon Street traffic at Dean Road, Winchester Street, Pleasant Street and Carlton Street, and to westbound Beacon Street traffic at Centre Street, and on all approaches to the Harvard Street intersection.

Several unsignalized crossovers have warning signs indicating a train crossing, but they are too small and too poorly maintained to be of real value.

To provide safer vehicular crossings, more control is needed to compensate for poor sight distance given to U turning, and cross traffic.

The following recommendations made by Bruce Campbell & Associates are presented here for consideration and study with municipal officials, as ways to alleviate the safety and capacity problems generated at each location.

Provide left turn storage lanes in the median along Beacon Street at the following locations for the direction noted:

Carlton Street	-	Westbound traffic
Kent St.-Powell St.	-	Westbound traffic
St. Paul Street	-	Westbound traffic
Harvard Street	-	Eastbound and Westbound traffic
Winchester Road	-	Westbound traffic
Winthrop Road	-	Westbound traffic
Regent Circle	-	Westbound traffic
Dean Rd.-Corey Rd.	-	Westbound traffic
Englewood Avenue	-	Westbound traffic
Strathmore Road	-	Eastbound traffic

Prohibit the following turning movements at the vehicular cross-overs indicated.

Hawes Street - All vehicular crossing movements except for eastbound U turning traffic.

Kent St.-Powell St. - Left turns for eastbound Beacon Street traffic during morning peak periods.

Charles Street - All U and left turning movements in both directions on Beacon Street.

Pleasant Street - All crossing and turning movements, except for emergency vehicles.

Westbourne Terrace - Left and U turning movements for westbound Beacon Street.

Washington Street - Left turning movements for southbound Washington Street, U and left turning for westbound Beacon Street.

Englewood Avenue - U and left turns for eastbound Beacon Street.

Strathmore Road - Westbound U turning for Beacon Street traffic and Strathmore Road traffic.

Ayr Road - All turning movements from Beacon Street.

Signalize the following crossovers:

Charles Street
Marion Street
Winthrop Road

b) Curb Barriers:

Several sections between Washington Street and Harvard Street along the southerly side of the median have no physical barriers to stop angle parked vehicles from encroaching on train tracks. To eliminate this situation it is proposed that curbing or highway guard rail be installed at all locations where vehicular parking may impede passenger or train movements and create accidents.

It is suggested that much of the work described above could be financed under the so-called "TOPICS" Program (Traffic Operations Program to Improve Capacity and Safety) of the Department of Transportation, Bureau of Public Roads. Those projects that could not be so financed should be undertaken as part of the Stage 1 program, with the municipality working closely together and sharing the expense.

D. SUMMARY OF TOTAL BENEFITS

Elimination of accidents due to human failure will be a major benefit of the new automatic train stop and cab signal system. The new system will prevent trains from exceeding speed limits or passing stop signals, and will aid the operator on lines where present wayside signals may be obscured in inclement weather.

Installation of pedestrian signals at selected locations will provide the necessary gap in vehicular traffic to enable pedestrians to cross the heavily travelled streets to board trains. Provisions for left turn lanes will separate left turning traffic from through traffic, thus reducing the accident potential. Improvement in vehicular operations will also occur due to the increased capacity of the approach. Signalization of certain intersections will provide safe movement for cross and turning traffic as well as for the main street and train traffic. Installation of fencing to channelize pedestrian movements will greatly reduce the number of conflicts between pedestrians and vehicular traffic.

Train radio will reduce crime in trains and stations, as well as speeding corrective action when incidents do occur. Station modernization, already underway as a separate program, will reduce opportunities for criminal activity and reduce or eliminate safety hazards.

V. INCREASE SYSTEM CAPACITY

INTRODUCTION

There are a number of areas within the Green Line system where capacity problems exist. They fall mainly into two groups:

those problems related to the vehicles, and those related to the configuration and operating characteristics of the infrastructure.

In the area of vehicles, capacity concerns not only the number of people which can be fitted into a vehicle or train, but also the number of people which can be moved on and off the vehicle when it stands in stations.

The principal capacity restraint in the existing Green Line network is Copley Junction--the point where a major and a minor branch join to form the central trunk line through downtown. The problems and solutions for this facility will be described in detail as they are applicable to other less serious problem areas as well.

A. INCREASE CAPACITY OF VEHICLES AND TRAINS

The clearance limitations imposed by the present subway tunnels preclude the use of cars very much larger than those now in use, unless an articulated car is used. The existing cars are 47'-0" long and are 8'-4" wide, with the exception of the 50 newest cars which are 8'-8" wide. the No. 6 car would be 50'-0" long and 8'-8" wide. The additional length and width will be used primarily to improve circulation of passengers by increasing the number of doors on the left side from one to two, and to provide space for operators' cabs at each end of a portion of the fleet. The loaded capacity of the No. 6 car would be 132 persons, of which 45 would be seated, slightly better than the present PCC cars. The use of articulated cars could increase capacity to 190 or more.

The improvement in boarding and alighting capability has been discussed in Section I in relation to dwell time improvements. As mentioned before, the stop time for present trains at platforms where left-hand loading through a single door is required, can be reduced by one-half with the new cars. As the total cycle time from one train to the next also includes time to accelerate and brake and an interval between trains, a reduction in dwell time by one-half certainly will not double line capacity at a station platform, but could result in a 25% to 33% increase. The reduction in dwell time brought about by the articulated design would further increase line capacity.

The bottleneck at Park Street and Government Center Station will be significantly relieved by the improvement in left-hand loading offered by the new cars. This improvement in capacity should make it possible to run more service north of Park Street. All or part of the Huntington Avenue service could be extended to

Government Center, improving access for passengers on that line and those boarding at Park Street who make connections with the Blue Line at Government Center. Actually, the more trains run between Park Street and Government Center, the less the stop time will be for trains at these stations as passengers will have more trains available, and those from Huntington who now must transfer at Park to other Green Line northbound trains could remain on their own trains, reducing the number of persons boarding at Park Street.

System capacity may be further increased by running longer trains. Existing signal block lengths and some surface stop platforms limit trains to three cars, and where street operation occurs such as the outer end of the Huntington Avenue Line, trains are limited to two cars. The new cars will be designed to permit operation of trains of up to six cars and appropriate changes in facilities can be made to allow use of these longer trains.

Today, the average length of train in the Green Line subway, inside of Copley Junction, is 2.5 cars in the peak periods. An increase only to 3, for example, would increase line capacity by 20%, and an increase in length of all trains to 4 cars would add 60% to capacity, assuming that the headway remains constant. However, it will probably not be practical to run 4-car trains until we have the capability to do it on all routes with the remaining street operation eliminated. The reason for this is that with 2 and 3-car trains, 2 trains can occupy a station platform in the subway simultaneously, as most platforms will hold 6 cars, except Park which can handle 8. Normally, loading of 2 trains at once in a station is done at Park and Government Center, and only occasionally at other locations. At the other stations the second train will usually hold back as it enters the station and wait for the train which is loading to finish and pull out.

In the typical peak period in the subway when the Watertown Line was in operation, approximately 70 trains per hour one way, averaging 2.5 cars in length, produced a flow of 175 cars per hour. To improve reliability, it would be desirable to reduce the number of trains and increase their length. If we ran 60 3-car trains per hour, the capacity would be nearly the same (180 cars per hour), but regularity due to reduced congestion would be considerably improved. With a completely new fleet, running in 4-car trains, this could rise to 240, an increase in capacity of 37% over the present service while number of trains per hour in the subway would be reduced by 14%.

B. INCREASE CAPACITY OF INFRASTRUCTURE

The major choke-point in the Green Line system today is at Copley Junction, where the Huntington Avenue branch meets the main line from Kenmore. As some of the techniques for dealing with the problems at this location are applicable to other junctions in the system, the proposal for Copley Junction will be discussed in detail.

1) Description of Copley Junction

This junction consists of a single-level or "flat" intersection between the double-track Boylston Street and Huntington Avenue subways, lying under Boylston Street just west of Copley Station. The Boylston Street subway, going outbound toward Auditorium Station, is on tangent; and the Huntington Avenue subway, going outbound toward Prudential Station, turns 90° to the south with a 140' radius curve. The track is nearly level through the junction. Copley Station platforms are staggered so that the west end of the outbound platform is 320' from the switchpoints, and the west end of the inbound platform is 50' from the switch-points. Each platform can hold six 48' long PCC streetcars (see Figure 10-4).

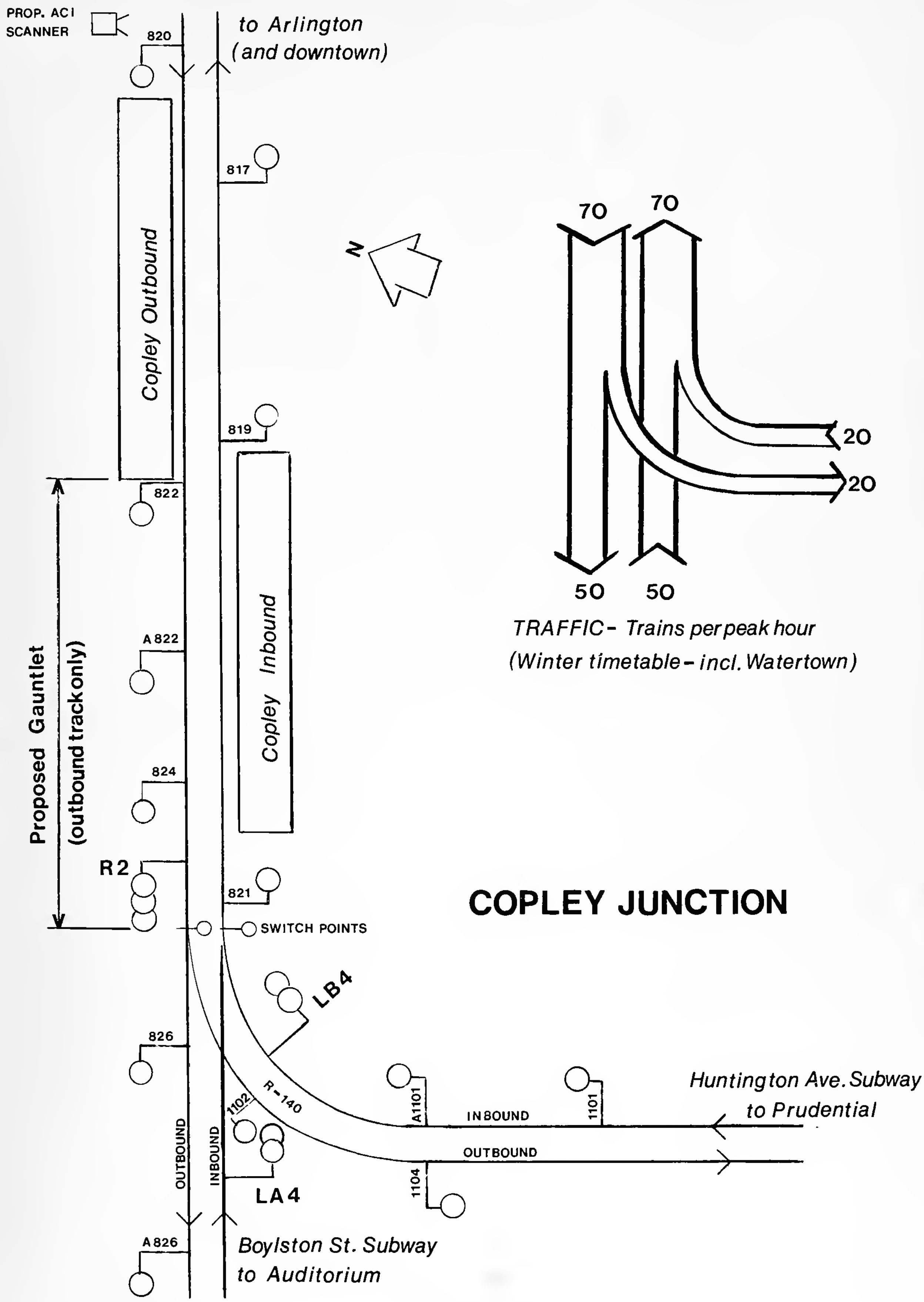
A discussion of the history of Copley Junction will be found in Chapter 6, and a discussion of the capacity problem on Page 6-12.

Copley Junction is protected by automatic signals, without train stop, with selection of diverging movements made by power-on or power-off operation of the train by the operator as it passes a contactor on the overhead trolley. Converging movements are on a first-come, first-served basis. The junction consists of the following segments of track:

Signals LA4 to 821:	Inbound Auditorium to Copley
Signals LB4 to 821:	Inbound Prudential to Copley
Signals R2 to 1102:	Outbound Copley to Prudential
Signals R2 to 826:	Outbound Copley to Auditorium

The first three of these segments make up the "critical area" of the junction where as many as ninety (90) train movements may occur in the peak hour, assuming a peak volume of 70 trains in each direction at Copley Station. The 90 movements are made up of fifty (50) inbound trains from Auditorium*, twenty (20) inbound trains from Prudential, and twenty (20) outbound trains

*Research was done while the Watertown Line was in operation, producing a maximum loading on the subway.


PROP. ACI SCANNER
820
to Arlington (and downtown)
817
Copley Outbound
819
822
Copley Inbound
A822
824
Proposed Gauntlet (outbound track only)
R2
821
SWITCH POINTS
LB4
826
R-140
1102
A1101
INBOUND
1101
OUTBOUND
1104
LA4
Huntington Ave. Subway to Prudential
Boylston St. Subway to Auditorium
A826
70
70
20
20
50
50
TRAFFIC - Trains per peak hour (Winter timetable - incl. Watertown)
COPLEY JUNCTION
N
FIGURE 10-4

to Prudential crossing the inbound track from Auditorium. Initial observations have shown that the critical area of the junction is thus occupied by trains approximately 1,600 seconds in a peak hour ($\pm$ 45% of the hour). Train length varies from one to three cars, averaging 2.5 cars.

2) Factors Limiting Capacity of the Junction

There are a number of basic factors now limiting the capacity and regularity of operation of the junction and these, to a great extent, are independent of one another. They involve characteristics of the junction, its approaches and the trains. The factors are as follows:

a) Degree of "Parallel Moves" Through the Junction:

This may be defined as the frequency which trains bound to and from a given branch meet at the junction. For example, if all trains to and from the Huntington Branch met at the junction, the at-grade crossing of the outbound track to Prudential and the inbound track from Auditorium would have no adverse effect on line capacity (other than the speed limitation of the curve and turnout). In actual practice, this occurs very seldom, and a near miss of only 20 seconds (approximate time for one train to clear the junction) is enough to mean that the junction is occupied twice as long as it would be by a simultaneous movement in both directions.

b) Speed of Movement Through the Junction:

Speed is limited by the geometric configuration of the tracks through the junction, by the need for many trains to accelerate from a full stop (or from a very low speed) while passing through the junction, and restrictions imposed by operating rules. An example is the "Alphonse and Gaston" route which occurs when trains from Copley to Auditorium meet trains in the opposite direction, and one holds back while the other clears the junction. This is done because of the fear that the outbound train might accidently throw or split the switch and head toward Prudential, colliding with the inbound train from Auditorium. This is a hangover from surface car operating procedure where railroad-type of point locking of switches was non-existent.

c) Length of Train Operated Through the Junction:

This is controlled by the design of the cars and of the routes feeding the junction. At present a mixture of 1, 2, and 3-car trains pass through the junction, with the average of peak period trains being 2.5 cars in length.

3) Proposals for Improvements

Ideal, long-range improvements which have been investigated include the following: reconstruction of the junction to grade-separate the conflicting movements; elimination of the junction by reconnecting the Huntington Branch to a new subway; or reducing traffic through the junction be rerouting the Highland Branch to a new subway. The latter two schemes all involve sizeable capital investments. Grade separation is physically feasible but very costly, and should not be undertaken until all other means of improvement have been exhausted. In lieu of major "civil-engineering" type solutions, the MBTA must strive to do everything possible with train control and other operational solutions.

The primary purpose of the proposed improvements is to reduce the amount of time that each vehicle (or train) occupies Copley Junction. The time thus saved may be used to run more or longer trains, or by holding the number of trains constant, reduce delays and irregularities of service at the junction.

The proposals described below "leave the door open" for applications of other medium or long-range solutions to Green Line problems. The capital cost will be low enough that even if the junction were completely eliminated within the next decade, the benefits would repay the investment many times over.

a) Automatic Traffic Control:

The duty of the Automatic Traffic Control System for Copley Junction is to replace the existing first-come, first-served operation with a programmed operation which will favor certain moves under proper conditions. It would be similar to systems now in use at street intersections where feedback from traffic provides inputs to the signal controller. The system could be overlaid upon the interlocking and in no way interfere with the safety of its operation. The system would be programmed to encourage parallel moves through the junction*, in particular the moves to and from

*"Parallel moves" means movements in opposite directions on the same branch at the same time. For example, trains to and from the Huntington Branch would pass over the junction at the same time.

the Huntington Avenue Branch. In the present rush hour situation, there is a fairly good chance that trains to and from Auditorium will meet at the junction, as this branch handles 50 out of the 70 trains passing each way through Copley Station. By maximizing the parallel moves on the other branch to or from Prudential, the conflicts of the at-grade intersection can be minimized. If all trains to and from Prudential met at the junction, the effective occupancy of the critical area of the junction would be 70 trains per hour, and if none met, it would be 90 trains per hour, a 28% increase in moves assuming that the critical area of the junction is occupied the same amount of time for both alternatives. It is not realistic to assume all trains on the Huntington Branch can be forced to meet at the junction due to the impossibility of controlling the input of trains from the street and from other congested areas within the subway. Figure 10-5 indicates how line capacity inside the junction would vary as the percentage of inbound and outbound Huntington Branch trains meeting at the junction is varied.

The traffic controller normally would be set up to hold inbound trains from Prudential at Signal LB4 until an outbound train to Prudential is ready to cross the inbound track from Auditorium at Signal R2 (see Figure 10-4). However, to avoid excessive delay to inbound trains from Prudential, a maxium time limit of, say, 1.5 minutes would be built into the program (the average headway on the Huntington Branch with 20 trains per hour is 3 minutes, but variations are very sizable). The program could be overridden automatically or manually if the inbound train has been preceded by a sizable gap in service.

Usually, it would be desirable to send outbound turning trains to Prudential as fast as they arrive. However, a subsidiary program could be set up to hold outbound and inbound turning trains, if there was a large queue of inbound trains from Auditorium and there were no more than one or two outbound trains waiting at Copley. This same routine could be used to give preference to an inbound train from Auditorium which had been preceded by a large gap in service.

The hardware required to accomplish these tasks includes the following major items:

1. A device to identify outbound trains, such as an ACI scanner with suitable labels on all cars. This would be located near the Arlington end of Copley Station, approximately 1 to 1.5 minutes run time from the junction. A second scanner would be placed at the approach to the Copley switch to operate it, in lieu of the present power-on, power-off control.

COPLEY JUNCTION :

PLOT OF LINE CAPACITY RELATED TO TRAIN LENGTH, AND TO % OF INBOUND & OUTBOUND MEETS OF HUNTINGTON BRANCH TRAINS AT JUNCTION--ASSUMING THAT THE CRITICAL AREA OF THE JUNCTION IS OCCUPIED 40 TO 45% OF THE PEAK HOUR (CONDITION WITH TYPICAL WINTER TIMETABLE)

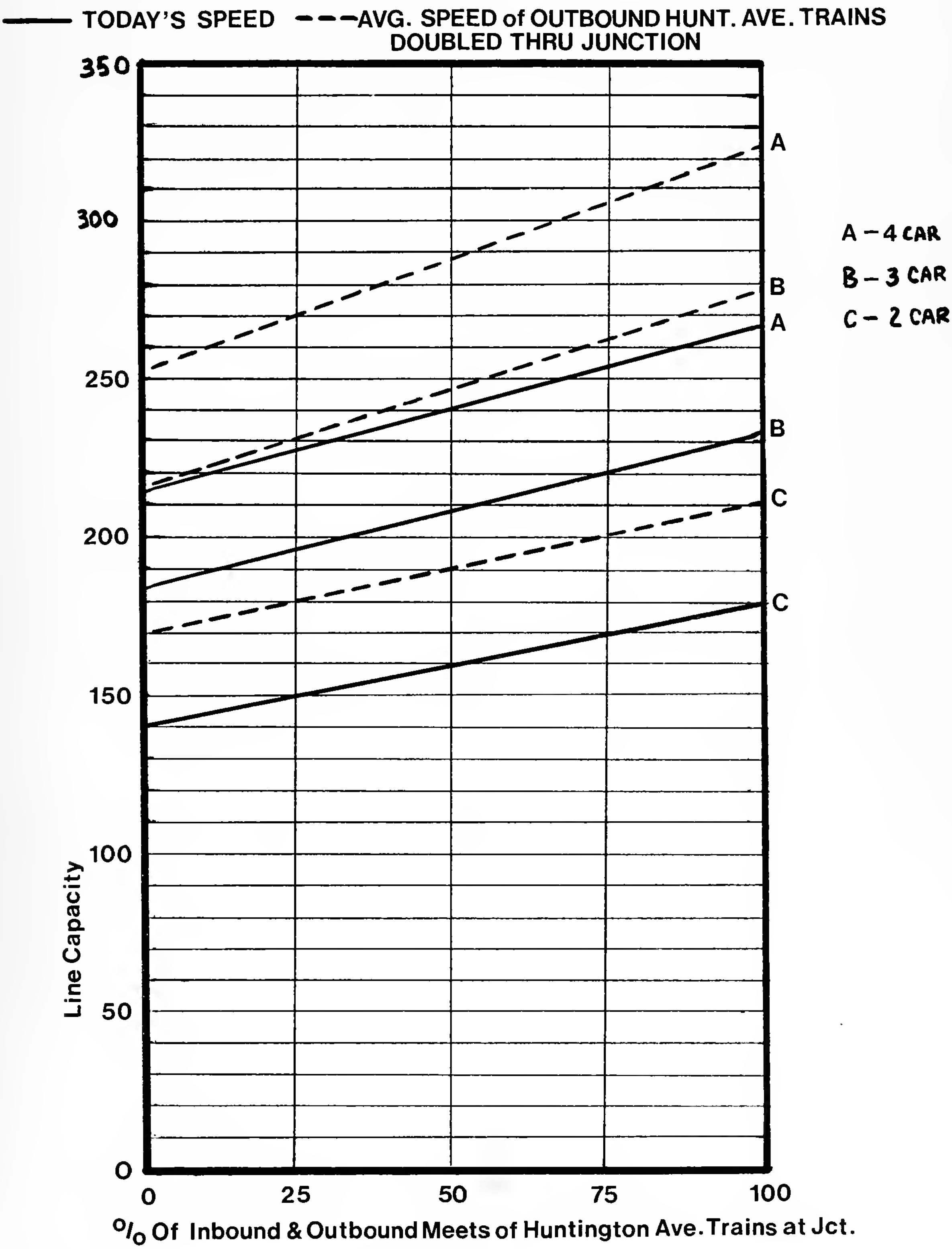


FIGURE 10-5

2. Devices to detect the presence of cars on the three approaches to the junction. Short track circuits or presence detectors could provide this information. The devices should be able to give the approximate number of cars or trains which occupy the approach areas at a particular time.

3. A time clock to inform the machine that it is in an A.M. or P.M. rush hour, a weekday, etc. Other timing devices to control the maximum wait for inbound trains from Prudential, and to keep track of gaps in service on the approaches to the junction, as well as the arrival time of trains waiting at the junction.

4. "Wait" signals at the junction approaches. These could be a separate signal indication, or could use existing Signals R2, LA4, and LB4. It is possible that wait signals could be moved back to hold trains at Auditorium and Prudential Stations instead of in the tunnel.

5. A "black box," the nerve center of the controller, containing the logic required to tie together the inputs from receptors 1, 2, and 3, and provide the outputs to Item 4. It would provide the necessary interface with the junction interlocking, the latter having full responsibility for the safety of the operation. Any failure of the "black box" and its associated receptors would restore complete control to the interlocking with first-come, first-served operation. A manual override and failure warning light should be provided at the junction, and at the Central District Supervisor's Office.

To summarize, the Traffic Controller, from time to time, would penalize a minority of cars and riders in order to improve the position of the majority. In effect, the short trains on longer headways on the Huntington Branch would be given less priority than the longer, more frequent trains on the "main line" toward Kenmore and the three western branches. Actually, by including the gap detecting feature on the three approaches, Huntington Branch trains in both directions could receive some preferential treatment.

b) Gauntlet Track Layout:

A gauntlet track would extend along the outbound track from Copley Station to Copley Junction (approximately 320'). The purpose of

this layout is to permit higher speeds through the junction for outbound trains to both branches. The relocation of switchpoints for the diverging move to the west end of Copley Station, where speeds of starting trains are low, in any case, will eliminate the chance of accidentally operating the diverging switch in the face of an oncoming train, splitting the switch or derailing there, which are the hazards of the existing layout. It appears that by eliminating the switchpoints at the junction, the average speed of the turning trains to Prudential could be nearly doubled, resulting in at least a 15% increase in capacity or savings in time at the junction. This is based on preliminary study of the existing operation, where outbound turning trains compose about 17% of the cars which pass through the critical area of the junction, but use up nearly 30% of the time which this area is occupied. (This assumes no meets of inbound and outbound Huntingtons at the junction.)

The gauntlet track would offer additional gains in capacity, or savings in time, for outbound trains headed to Auditorium. No longer would they be required to go through the aforementioned "Alphonse and Gaston" routine, and will be able to clear out of the junction approach at a 25% to 33% higher average speed than at present.

c) Increased Train Length:

Although not an improvement to the actual infrastructure of the junction, as were the previous two items, an increase in average train length will increase junction capacity and/or reduce delays. It is obvious that one 4-car train will occupy the junction less time than two 2-car trains. Figure 10-5 indicates variations in capacity for 2, 3, and 4-car trains, in conjunction with those due to improvements in train control and speed.

Implementation of the traffic control system, plus the gauntlet track layout, can increase the number of trains over those now run by 25% to 40%, or if the number of trains is held more or less constant, a major decrease in delay time and irregularities at Copley Junction is possible. Raising the average train length will bring even more benefits. Thus, congestion at the most serious bottleneck in the Green Line system can be greatly relieved. Application of this type of control to Beacon Junction and junctions at Kenmore, Park Street, Government Center and Haymarket will improve train operations as well, although the problems and the benefits from solving them are less spectacular than the case of Copley Junction.

4) Other Signal and Operational Improvements

The new cab signal system with train stops will help increase capacity in several ways. The improved reliability it will offer, along with other improvements in reliability discussed in previous sections, will give us a better chance of achieving the theoretical capacity of the line. The automatic signal system, plus the junction controllers, provides a given number of "slots" for entering trains to fill and pass through the system. By decreasing random delays and increasing opportunities to compensate for delays, more "slots" will be filled, maximizing capacity.

The security offered by automatic train stop will reduce delays at junctions and other speed restricted areas. This will reduce stop-and-go operation, speeding up traffic through critical areas thereby increasing line capacity as well as overall speed and reliability.

Completion of a public address system (provisions have been made in modernized stations) will help maximize the utilization of vehicles and trains. Provision should be made for connecting portable microphones at several locations along busier platforms. Thus, train starters will be able to direct passengers onto the more lightly loaded cars, taking better advantage of the train space being provided. The P.A. system within the vehicles will assist in promoting better use of car space.

The automatic destination sign system will also help reduce confusion on the platforms and promote faster loading which will reduce stop times and increase capacity.

C. SUMMARY OF TOTAL BENEFITS

Increased capacity at Park and Government Center Stations will result from use of new vehicles with doubled left-hand loading capability. At left-hand loading platforms through-put with new cars will be 25% to 33% better than with the present fleet. This will permit the running of additional service from Park Street to Government Center or beyond. The ability to run longer trains has the potential of raising the present one-way peak hour flow by 39%, from approximately 175 cars (in 70 trains) to as much as 240 cars (in 60 trains), assuming all trains with four cars each.

Improvement of Copley Junction with a new traffic control system can offer an increase of 25% to 40% in cars per hour through the junction. Increasing train length would add further to this capacity. Most of the benefits, however, are expected to come

in the form of smoother operation and minimized delays. When the new cars are put into operation, it is not expected that the schedules will call for more than 60 trains per hour east of Copley (or one-minute headways). Scheduling shorter headways would reduce line speed and would not be taking advantage of the performance capababilities of the new cars. Therefore, the total number of moves through Copley Junction may not be much different from present operation. The added capacity will be reflected in faster operation through the junction, much fewer delays, and the ability to handle longer trains.

The general improvement in system reliability brought about by new signals, communications and other changes will result in improved system capacity by reducing random delays and maximizing use of the time available to move trains through critical areas.

In all, significant improvement in system capacity will be possible with new cars and operating controls, making major investment in new tunnels unnecessary for some years to come.

Table 10-2 summarizes the various improvements by categories, and indicates how each one meets the performance goals outlined at the beginning of this chapter.

VI. CONTROL COST OF OPERATION

INTRODUCTION

Many aspects of the physical plant or equipment, and the way it may be operated, which affect cost of operation have been touched upon in the previous sections of this chapter. Therefore, this section can only briefly summarize the areas in which operating costs may be stabilized or reduced as a result of the Stage 1 Program. Because operating costs are so closely tied to operating rules and contract agreements which are not a part of this study, and due to the fact that the part which the consumer feels the fare or deficit assessment he pays is influenced by the characteristics of the entire MBTA system, it is possible to point out only the more general directions in the way of economic benefits which the program will offer.

The control of cost of operation of the Green Line System will be affected in the following areas:

- Reduction in cost of normal scheduled operations.
- Reduction in maintenance costs.
- Reduction in costs incurred by abnormalties of system operation.

Table 10-2

STAGE 1 IMPROVEMENT CHECK LIST

Specific Improvements	PERFORMANCE GOALS: Reduce Overall Travel Time	Improve Reliability of Service	Improve Rider and Community Environment	Improve Safety and Security	Increase System Capacity	Control Cost of Operation
Vehicle Related Improvements:						
Higher Maximum Speed	X	X			X	X
Improved Suspension			X			
Additional Doors	X				X	X
Lower Vestibules	X		X	X	X	X
Air Conditioning			X			
Noise Control			X			
Padded Seats			X			
Double End Capability		X				X
Longer Train Capability					X	X
Train Radio and P.A.		X	X	X	X	X
Cab Signal and Train Stop	X	X		X	X	X

Table 10-2
(Continued)

Specific Improvements	PERFORMANCE GOALS: Reduce Overall Travel Time	Improve Reliability of Service	Improve Rider and Community Environment	Improve Safety and Security	Increase System Capacity	Control Cost of Operation
Roadway Related Improvements:						
Improved Drainage	X	X	X			X
Increase Superelevation and Realign Curves	X		X			X
Replace Work Track Material	X	X	X			X
Weld Joints and Grind Rail	X		X			X
Reballast and Realign Track	X					X
Relocate Surface Tracks and Channelize Traffic	X	X		X	X	X
Provide New Crossovers		X				X
Eliminate Clearance Problems	X				X	
Lengthen Surface Platforms				X	X	
Eliminate and Consolidate Stops	X	X		X		X
Provide New Shelters			X			
Provide Noise Control			X			
Erect Fences and Barriers	X		X	X		X

Table 10-2
(Concluded

Specific Improvements	Reduce Overall Travel Time	Improve Reliability of Service	Improve Rider and Community Environment	Improve Safety and Security	Increase System Capacity	Control Cost of Operation
	PERFORMANCE GOALS					
Signal, Communication and Power Related Improvements:						
Cab Signal	X	X		X	X	
Automatic Train Stop	X	X		X	X	X
Train Radio		X		X		X
Public Address in Stations	X	X	X		X	
Automatic Junction Control	X	X			X	X
Improved Line Supervision		X		X	X	X
Automatic Destination Signs	X		X		X	
Street Traffic Signal Coordination	X	X		X		X
New Substations	X	X			X	X
Upgraded Trolley and Feeders	X	X			X	

Like the achievement of the other improvement goals, the improvements in operating cost will result from a multitude of small improvements, some of which are independent of one another, and others which must be as part of larger packages of related improvements.

A. REDUCE COST OF NORMAL SCHEDULED OPERATIONS

The major benefits in this area will result from the reduction in travel time. Purchase of a complete fleet of cars, and completion of all of the associated improvements, will allow trains to cover their assigned runs in a shorter period of time. The improved productivity of vehicles and tracks will mean that for a given amount of traffic, fewer cars and men will be needed, or that the same personnel could handle an increased amount of traffic.

On the Highland Branch for example, the reduction in peak period travel time from Riverside to Lechmere of at least 10 to 13 minutes in one direction, amounts to a saving in round trip time, including layovers, of nearly 20%. Because of work rules and contract agreements, and relationship of this particular route to the rest of the manpower pool for the Green Line, this may not be directly translatable to an absolute labor saving of 20%, but it should approach this as a maximum possible saving for this particular line with all improvements in place.

The other routes where time savings are less significant will have less relative saving in manpower. It has been estimated however that the entire Green Line network when improved could have a total saving in labor cost per car mile of at least 10%. An alternative program was considered which made all the plant improvements, but replaced only one-half the car fleet, but this program resulted in only half the possible savings.

B. REDUCE MAINTENANCE COSTS

A sizeable improvement in maintenance costs will result from the replacement of overage, worn out cars and facilities. In addition to requiring frequent attention, the old equipment is often difficult to maintain and requires parts which are hard to obtain. The replacement of old hardware or material with new will decrease the amount of work required, will make the work easier to do, and will draw from a large reservoir of current off-the-shelf standard parts and supplies. For example, the time and effort now spent fabricating an out-of-stock part for a PCC car or a switch machine, will be virtually eliminated by complete replacement with new equipment.

In the case of car equipment, there will be some additional hardware, such as air conditioners, cab signal equipment, and train radios, which we do not have on the present cars, and this will require additional facilities and specialized work force. In spite of the increased sophistication, the fact that the cars are new, are designed for the service by utilizing more robust components, and designed for easier maintenance through use of component replacement, it is expected that the new fleet will permit economies in the area of maintenance. An additional factor which will contribute to maintenance savings is that a smaller fleet will be required due to the higher speed capabilities of the cars and the upgraded roadbed, power and signal systems.

The upgraded roadbed will have to be kept at a higher standard, particularly the Highland Branch, but replacement of worn track material with new heavier components, along with improved drainage, additional ballast, welded rail joints, and proper rail anchoring, will help the renewed track stay-put, retaining a good ride quality for a longer period of time.

The new cab signal system will permit the retirement of wayside signals with their associated maintenance problems. Replacement of the old pneumatic switch machines with new electric machines will eliminate a major maintenance and reliability problem.

A major means of holding maintenance cost to a reasonable level, and simultaneously controlling maintenance quality, is to provide proper facilities and equipment for doing maintenance work. The Stage 1 Program includes funds for a new car shop at Riverside and improvements at Reservoir Car House. The latter facility, which now must handle the bulk of the routine maintenance and inspections of the Green Line fleet dates from the horse-car era, and is woefully inadequate. Major overhaul requires moving cars by trailer truck to Everett Shops. Because of the difficulty of moving cars there, they often must be dealt with in car houses, ill-equipped for handling such work.

The new shop with new equipment will make it easier to do the necessary work, and will produce a better product than is possible at present.

C. REDUCE COSTS INCURRED BY ABNORMAL OPERATIONS

The scope of the reliability problem and possible solutions have been discussed earlier in this chapter. Here, it is necessary to mention that unreliability costs money in terms of direct labor costs for train operation and repair, and in the area of accidents and resulting claims.

Serious disruptions to service, which are all too-frequent today, can increase operating costs by adding to the amount of overtime worked by operating personnel.

Other costs can be incurred if buses are called out to perform emergency service when a rail line is tied up. In the case of a derailment, or major failure of the tracks, power, or signal systems, overtime labor and materials must be expended in order to restore service.

Accidents to pedestrians and motor vehicles can be extremely costly both in disruptions to service, and particularly in the expense of settling damage claims. The improvements in traffic safety proposed for the reservation routes should go far in reducing the amount of damage claims.

D. SUMMARY OF BENEFITS

Implementation of the complete Stage 1 Program will make it possible to stabilize operating costs in some areas, and make actual reductions in others. It is estimated that the savings in running time brought about by a complete new fleet of cars, and associated improvements, will permit a reduction in the labor costs for train operation of at least 10%. Replacement of worn out equipment or facilities with new, utilizing items designed and specified to meet our service requirements, will hold down the cost of maintaining the system. Provision of proper car maintenance shops and equipment will allow us to do a higher quality, more efficient job. Improvements in system reliability will drastically reduce the overtime and other work required to restore service after major disruptions. New safety features incorporated in the signal system, and the surface reservation improvements will reduce the effects of accidents and the extent of damage or injury claims.

The following two Tables, 10-3 and 10-4, give the results of a staff study of projected operating costs, based upon an assumption of 10% labor saving in cost per mile for operation and maintenance for the new cars and their related facilities.

Table 10-3 gives the operating costs of the present Green Line system, compared with the projected operating costs following completion of the recommended Stage 1 Program. This program assumes acquisition of a full fleet (220) of new Green Line cars, and discontinuance of the remaining surface street operation. This means that the Huntington Avenue Line would operate to a new terminal near the intersection of Huntington and South Huntington Avenues (see Page 10-20), and the remainder of the line to the Arborway would be replaced by buses. Twenty-two (22) new buses would be required.

Table 10-3

GREEN LINE - COST OF PRESENT OPERATION

Routes	Peak Hour Headway	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Riverside to Lechmere	5 Minutes	$7,879,945	3,018,789	66
Cleveland Circle to Lechmere	5 "	3,517,225	1,347,441	54
Boston College to North Station	4 "	4,109,624	1,574,388	60
Arborway to Park Street	3 "	4,536,419	1,737,892	54
TOTALS:		$20,043,213	7,678,510	234

COST OF OPERATION UNDER RECOMMENDED STAGE 1 PROGRAM

Routes	Peak Hour Headway	Cost of Operation	Yearly Mileage	Cars Required For Schedule
Riverside to Lechmere	5 Minutes	$7,091,739*	3,018,789	60
Cleveland Circle to Lechmere	5 "	3,165,408*	1,347,441	48
Boston College to North Station	4 "	3,698,552*	1,574,388	54
Huntington Avenue (to New Terminal)	3 "	2,733,185*	1,163,404	36
Arborway to Huntington Avenue (New Terminal)	2 "	539,697	349,160 Buses	20 Buses
TOTALS:		$17,228,581	7,104,022 Cars	198 Cars
			349,160 Buses	20 Buses

*Denotes an assumption of 10% savings in cost per mile, compared with present operation.

	For Schedule (90%)	Spares	Purchase (100%)
Cars Recommended:	198	22	220
Buses Recommended:	20	2	22

Table 10-4

GREEN LINE - PROJECTED COST OF OPERATION

Variations of Stage 1

	Routes	Peak Hour Headway	Cost of Operation	Yearly Mileage	Cars Required For Schedule
A.	Purchase only 130 new cars:				
	Riverside to Lechmere	5 Minutes	$7,485,691*	3,018,789	60 New
	Cleveland Circle to Lechmere	5 "	3,517,225	1,347,441	54 Old
	Boston College to North Station	4 "	4,109,624	1,574,388	60 Old
	Arborway to Park Street	3 "	4,309,450*	1,737,892	48 New
	TOTALS:		$19,421,990	7,678,510	108 New 114 Old

*Denotes an assumption of 5% savings on cost per mile compared with present operation. Savings will be primarily applicable to the surface operation only, since operating savings in the subway will be limited by the presence of the old equipment.

The above plan was based on the assumption that 130 cars would be sufficient to operate Beacon, Commonwealth, and the shortened Arborway Line at such time as the Riverside Line was diverted out of the Central Subway and converted to high-platform operation. It is not now recommended because the full benefit of the new cars and other improvements cannot be obtained.

	Routes	Peak Hour Headway	Cost of Operation	Yearly Mileage	Cars Required For Schedule
B.	Purchase 234 new cars, enough for the entire Green Line:				
	Riverside to Lechmere	5 Minutes	$7,091,739*	3,018,789	60
	Cleveland Circle to Lechmere	5 "	3,165,408*	1,347,441	48
	Boston College to North Station	4 "	3,698,552*	1,574,388	54
	Arborway to Park Street	3 "	4,082,655*	1,737,892	48
	TOTALS:		$18,038,354	7,678,510	210

*Denotes an assumption of 10% savings in cost per mile compared with present operation.

The above plan was based on retaining the streetcar operation all the way to the Arborway. It is not now recommended because continued street running will subject the system to excessive delays. The new larger cars are not well suited for street operation. Access to the Arborway shop will no longer be needed.

Table 10-4 gives projected operating costs for two variations of the Stage 1 Program that were considered, but are not being recommended. They are shown for comparison only.

In closing, it should be emphasized that the full benefits of the Stage 1 Program can only be realized if all the Stage 1 recommendations are carried out. Summarizing, these comprise:

1. A complete new fleet of Green Line cars.
2. Track and roadway improvements.
3. Power system improvements.
4. Signal and communication improvements.
5. New vehicle maintenance facilities.
6. Buses to replace trolleys on the outer end of the Huntington Avenue Line.

Halfway measures will produce less than halfway results. Although the CASS study has shown that it would be possible to equip the remaining PCC cars with train stop protection and operate them in the Central Subway with the new cars, the full benefit of the new cars cannot be realized unless all of the PCC cars are eliminated. Further, it would be impossible to operate the new Green Line cars without corresponding improvements in power supply, track, signalling, and maintenance facilities. While there may be room for economies here and there in the program, the basic program must be adopted as a package. The alternative is to stay with the present type of PCC car operation.

The following pages contain an outline of the recommended Stage 1 Program, with cost estimates.

VII. THE RECOMMENDED STAGE 1 GREEN LINE PROGRAM SUMMARY AND ESTIMATES

A. NEW ROLLING STOCK

Scope

1) 220 new light rail surface-subway cars. Cars will be air conditioned and will have much higher standards of performance and comfort than the present PCC cars. (This quantity of cars is based upon assumptions of size, configuration, and performance characteristics of the "No.6" car, as well as a hypothetical schedule. This quantity may be revised when more specific information is available.)

Estimated Cost:	$39,600,000

2) 22 new air-conditioned buses to replace the present PCC car street operation on the outer portion of the Huntington-Arborway Line.

Estimated Cost:	814,000
Total Rolling Stock:	$40,414,000

B. TRACK AND ROADWAY IMPROVEMENTS

1) Central Subway and Lechmere Viaduct

Scope

a) Replace approximately 40% of worn rail, ties and hardware with new 115 lb welded rail. Realign all track and reballast where required. Weld remaining rail joints and grind corrugated rail.

b) Add three emergency single crossovers (near Arlington, Lowell Street and Lechmere).

c) Modify track and structure to provide clearance for new cars.

d) Provide turnback and storage track at Canal Street Station.

e) Extend platforms at Science Park Station to accommodate 4-car trains.

f) Provide Acoustic treatment at sharp curves in subway and on structure.

Estimated Cost:

a)	Track Improvements	$1,056,000
b)	New Emergency Crossovers	156,000
c)	Clearance Improvements	900,000
d)	Canal Street Work	260,000
e)	Science Park	40,000
f)	Acoustic Treatment	300,000
	Total	$2,712,000

2) Highland Branch - 9.4 Miles

Scope

a) Replace approximately 40% of worn rail, ties and hardware with new 115 lb. welded rail. Realign and reballast all track incorporating new super-elevation and spirals. Weld remaining rail joints and grind corrugated rail. Resurface platforms to accommodate track improvements and lengthen for 4-car trains where required.

b) Improve drainage of roadbed.

c) Add three single and four double crossovers.

d) Reconstruct Riverside Yard trackage to accommodate new car shop.

e) Rehabilitate station shelters, adding radiant heating and at two stations install facilities for part-time fare collection.

Estimated Cost:

a)	Track Improvements	$2,376,000
b)	Drainage Work	90,000
c)	New Crossovers	600,000
d)	Reconstruct Riverside Yard	762,000
e)	Station Work	180,000
	Total	$4,008,000

3) <u>Huntington Avenue Line - 1.4 Miles</u>

<u>Scope</u>

a) Track relocation, reservation, fences and platform changes over a length of 1.0 miles, and relocation of storage track at Northeastern, to be done in conjunction with widening of Huntington Avenue between the portal and Brigham Circle to be done by the City of Boston.

b) Relocation of track from street to new reservation west of Brigham Circle, and turnback loop with storage track, bus loop, and passenger shelter to provide a new terminal for the Huntington Line at South Huntington Avenue between Huntington and Heath Street. Final design and location to be determined in coordination with future redevelopment and traffic improvements by the City of Boston.

<u>Estimated Cost</u>:

a)	Track Work East of Brigham Circle	\$ 480,000
b)	Track Work and New Terminal	1,200,000
	Total	\$1,680,000

4) <u>Beacon Street Line - 2.4 Miles</u>

<u>Scope</u>

a) Relocate track and platforms, modify traffic circulation at Coolidge Corner.

b) Relocate and consolidate platforms, upgrade track, provide new fences and barriers, new shelters, and improved lighting of stops and crossings at selected locations, and modify track work entering Reservoir Yard. Install a double crossover at St. Mary's Street. Channelization changes and traffic signals other than those required for MBTA improvements will be by the City.

<u>Estimated Cost</u>:

a)	Coolidge Corner Work	\$360,000
b)	Improvements at Other Locations	240,000
	Total	\$600,000

5) <u>Commonwealth Avenue Line - 4.0 Miles</u>

a) Relocate and consolidate platforms, upgrade track, provide new fences and barriers, new shelters, and improved lighting of stops and crossings at selected locations east of Chestnut Hill Avenue (area west of Chestnut Hill Avenue has just been rebuilt). Install single crossovers at Warren Street and Chestnut Hill Avenue. Channelization changes and traffic signals other than those required by MBTA improvements will be by the City.

<u>Estimated Cost</u>:

a)	General Improvements	$600,000
	Total Track and Roadway Improvements:	$9,600,000

C. POWER SYSTEM IMPROVEMENTS

<u>Scope</u>

a) Provide new substations with two 2000 KW units in each at Riverside, Chestnut Hill and Fenway.

b) Provide new feeders and switches at selected locations.

c) Upgrade overhead trolley including modifications at low overhead bridges, changes to accommodate realigned trackage and new crossovers.

<u>Estimated Cost</u>:

a)	Three New Substations	$2,340,000
b)	New Feeders	300,000
c)	Upgrade Trolley System	960,000
	Total	$3,600,000

D. SIGNAL AND COMMUNICATION IMPROVEMENTS

<u>Scope</u>

a) Equip all Green Line cars and the Central Subway with a train radio system. Equip all Blue Line cars and the East Boston tunnel with a train radio system.

b) Provide a cab signal system with automatic train stop on all Green Line cars, and on all rail trackage except for the three surface reservation lines.

c) Provide automatic traffic control system and new interlockings to handle all moves at Copley and Beacon Junctions, and to control converging moves at Kenmore, Park, Government Center and Haymarket. Provide electric locking for all emergency crossovers.

d) Provide train identification system at selected Green Line points tied to the central dispatcher for purpose of line control.

e) Provide a public address system at all stations in the Central Subway and on the Lechmere Line.

f) Provide automatic destination signs at all Central Subway station platforms serving multiple destinations.

Estimated Cost:

a)	Train Radio (Green Line)	$ 1,116,000
b)	Cab Signal with Train Stop	9,588,000
c)	Junction Control and Interlockings	2,160,000
d)	Train Identification	552,000
e)	Public Address System	144,000
f)	Automatic Destination Signs	360,000
	Total	$13,920,000

E. VEHICLE MAINTENANCE AND REPAIR FACILITIES

Scope

a) Modernize Reservoir Car House to provide new employee facilities, improved fire protection, a new car washer, new car body hoists, and other labor-saving devices.

b) Construct a new car house, shop and yard, with equipment at Riverside capable of handling routine repair for a portion of the fleet, and major repair and overhaul for the entire Green Line fleet.

Estimated Cost:

a)	Reservoir Improvements	$ 500,000
b)	New Riverside Facility (Excludes Yard Trackage)	8,380,000
	Total	$ 8,880,000

Total Green Line Stage 1 Recommendations: $76,414,000

VIII. THE RECOMMENDED BLUE LINE PROGRAM

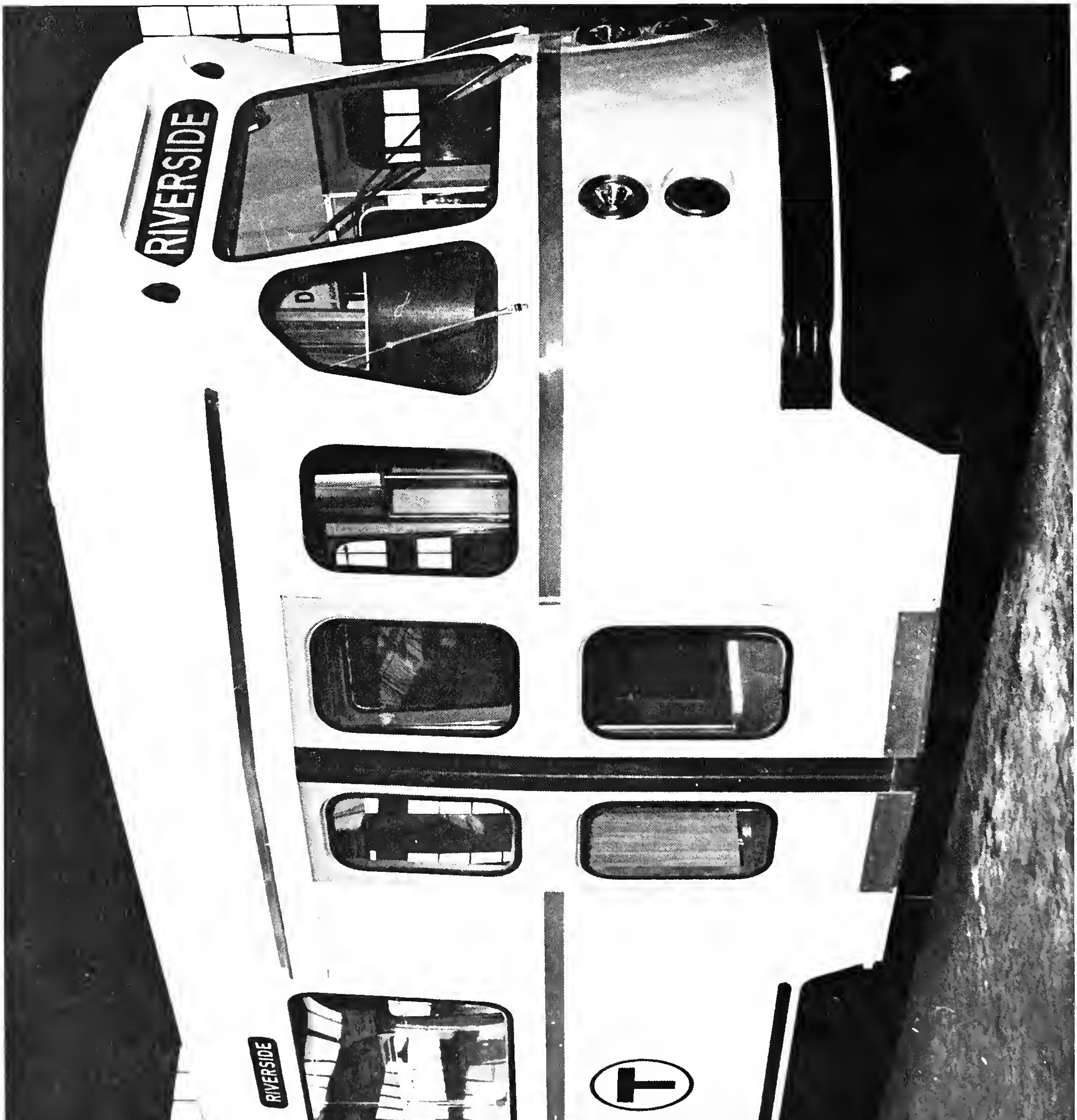
a)	32 New Rapid Transit Cars	$ 6,400,000
b)	Train Radio	600,000
Total Blue Line Recommendations:		$ 7,000,000

GRAND TOTAL RECOMMENDATIONS: $83,414,000

SUMMARY OF TOTAL RECOMMENDED IMPROVEMENTS

A)	New Rolling Stock:		
	1) Green Line		
	Cars	$39,600,000	
	Buses	814,000	
	2) Blue Line	6,400,000	
	Total		$46,814,000
B)	Track and Roadway Improvements		
	1) Subway and Lechmere	$2,712,000	
	2) Highland Branch	4,008,000	
	3) Huntington Avenue	1,680,000	
	4) Beacon Street	600,000	
	5) Commonwealth Avenue	600,000	
	Total		9,600,000
C)	Power System Improvements		3,600,000
D)	Signals and Communication		
	Green Line	$13,920,000	
	Blue Line	600,000	
	Total		14,520,000
E)	Vehicle Maintenance and Repair Facility		8,880,000
	TOTAL		$83,414,000
	Green Line		$76,414,000
	Blue Line		7,000,000
	TOTAL		$83,414,000

Note: All costs include engineering and supervision, contingencies, and where applicable, allowance for doing work under traffic.



Mockup of Proposed "No. 6" Car

FIGURE 10-6

CHAPTER 11

LONGER TERM CONSIDERATIONS

A STAGE 2 PROGRAM

The Stage I Program for rehabilitating the Green and Blue Lines represents a very major capital investment, and its implementation will require an intensive effort in terms of detailed planning, co-ordination, manpower and material. Furthermore, unlike the construction of a new line extension, most of the proposed work will have to be carried out under conditions of traffic, interfering as little as possible with the comfort and safety of the riding public.

Even the Stage I Program, however, will not accomplish all of the changes and improvements that are considered desirable. It would not be realistic to expect any single program to fully compensate for all the years during which public transit service has been allowed to deteriorate and fall behind the times technologically.

Even if the money were available today, Stage I would take three to four years to complete, and there will be plenty of opportunity for further improvements after that. As discussed in the conclusions and recommendations, we are not yet ready to recommend adoption of any of the three major system solutions which have been proposed (see Chapter 9). But there are a number of individual elements within each system which may well be worth adopting within the next few years, after some of the results of Stage 1 can be observed. These individual improvements could form the basis for a "Stage 2" Program. Some of them may not need to wait for the completion of Stage 1, especially when planning in conjunction with other agencies becomes clarified in certain areas, and if additional funds can be made available.

Following is a list of some improvements that should definitely be planned for a Stage 2 program.

1. Rebuilding of Park Street (Green) Station. The three major system solutions discussed in Volume II and in Chapter 9 of this volume, all call for major rebuilding of Park Street Station, resulting in a greatly improved facility for Green, Red, and Blue lines. If, after Stage 1 is completed, it appears that the construction of such a combined station will still be some time in the future, and if the new Type 6 cars solve the present loading problems at left-hand platforms,

as is hoped, then it may be desirable to run all Green Line service through Park Street, turning back at Government Center, Canal Street, and/or Lechmere. With all double-ended equipment, the loop at Park St. would no longer be needed.

Under these conditions the upper level of Park St. station should be rebuilt so as to eliminate the loop and the extremely sharp reverse curves on the southbound track entering the station. It would probably be desirable to retain the present four tracks, so as to provide for multiple berthing and faster loading, but no trains should terminate at Park St. under normal conditions, after completion of these improvements.

2. Rebuilding of Boylston Station. The problems at Boylston Station were thoroughly discussed in Chapters 6 and 8, and further detail will be found in Volume II. If, after the completion of Stage 1, it appears that one of the system solutions involving a new tunnel under Boston Common will not be adopted, and if a final decision has been made as to the use, or non-use, of the abandoned Tremont St. subway, then the Authority should proceed with the rebuilding and modernization of Boylston Station.

   The sharp curve at the South end of the station could be eased considerably, and the mid-platform reverse curves eliminated. Re-arrangement of platforms and passageways could reduce the cost of staffing and maintenance.

3. Alteration of Canal St. Loop Facility. The Stage 1 Program calls for certain improvements and additional storage capacity at the Canal Street Loop. The new Type 6 cars will not be able to negotiate the present loop, so that turnback tracks will have to be provided as part of Stage 1. After all the PCC cars are gone, the loop itself can be eliminated. After the Orange Line structure is demolished (in 1973 or 1974), additional storage tracks and improved passenger facilities, including possible bus transfer facilities, can be provided. Additional commercial development in the form of air rights should be investigated in conjunction with these improvements.

4. <u>Extension to Pines River</u>. As discussed in Chapter 4, a Blue Line extension from Wonderland to Pines River is justified. It should be included as part of a Stage 2 program, unless the Authority's BIPED development project shows real promise by the time Stage 1 is fully implemented. The BIPED (Bi-Powered Equipment Development) Project is discussed near the end of this chapter.

   It should be possible to design a less costly terminal than that recommended by the consultant in Volume IV. Also, present indications are that the proposed Revere Beach Connector from Interstate Route 95 may not be built by the time we are ready to proceed with the Pines River extension. This would offer an opportunity for co-ordinated design, with a saving in the cost of access ramps to the parking area.

5. <u>Modernization of Auditorium Station</u>. This station is the only major subway station on the Green Line not to be affected either by prior modernization, or rebuilding as part of a Stage 2 program. New lighting and graphics should be installed, and access from the surface at both east and west entrances should be improved.

   Modernization of Auditorium Station could be done without conflicting with any changes that might later be made as a result of adoption of a System 1 solution (routing the Riverside Line via the B&A right-of-way).

Although the need for the five improvement projects listed above is clear, the timing for implementation of the first four will be somewhat dependent upon other decisions yet to be made. Therefore, a firm timetable for implementation of a Stage 2 program cannot be recommended at this time. The Authority should plan, however, to make major improvements at Park Street and Boylston as soon as the results of the Stage 1 Program can be evaluated.

FOR FURTHER CONSIDERATION

The following listed improvements are ones which will require further study before any could be considered as recommendations for inclusion in a Stage 2 program. We are not attempting to list below all of the possible improvements that are included in various stages of the system solutions discussed in Chapters 3, 4 and 9. These are discussed at length in this volume, and in

Volumes II and IV. Rather, the below listed items are ones which appear to have merit but require further study. They would lend themselves well to construction as individual items without having to be part of any overall system solution.

1. Rehabilitation of the East Cambridge Viaduct. The problems of the elvated line to Lechmere have been discussed in this volume. Some possible solutions were suggested in Chapter 8 and are discussed in some detail in Volume II. The elimination of the Causeway Street elevated structure is still one of the Authority's objectives, but no clear solution has yet been found. When the requirements of future service to Somerville and beyond are more clearly known, then the Authority should proceed with the rehabilitation of the East Cambridge viaduct either as a busway, or an improved rail line. If the line is to remain as a rail line, then the Causeway and Lowell St. elevated portions should be replaced with a subway.

2. Somerville Extension. We have seen in Chapter 7, that Somerville ranks quite low among the "Inner Cities" in the percentage of total trips to Downtown. In other words, it is not particularly Downtown-oriented. Nevertheless, because of its population, Somerville ranks high in the absolute number of trips to downtown by all modes, and highest of all in the absolute number of transit trips to downtown.

   A detailed study of the transit needs of the City of Somerville and communities in that area was beyond the scope of the CASS Project.

   Because of the relatively heavy dependence of Somerville residents on public transportation, the possibility of a rail extension into Somerville should continue to receive serious study, but the close proximity of the Red and Orange lines, and the high priority needs for capital in other areas, ruled out the recommendation for such an extension in Stage 1. The one-mile extension proposed in the 1966 Program for Mass Transportation was not long enough and its terminal not well enough situated to attract many walk-in passengers, or to significantly relieve the congestion of buses in local streets. Certainly it was no attraction for park-and-ride customers.

Nothing in the Stage 1 program would preclude an extension from Lechmere into Somerville as a part of a Stage 2 program, utilizing low-platform cars with on-board fare collection. Such an extension, if built, should go beyond the Washington Street terminal proposed in 1966, and should be combined with the improvements discussed in #4 above. The logical route for such an extension would be along the Boston & Maine Railroad's New Hampshire Division right-of-way.

3. South End - Roxbury Extension. Present Authority plans call for the removal of the Washington Street elevated structure of the Orange Line, and relocation of that line to the present Boston & Providence right-of-way. While this work will provide an excellent rapid transit service over a wide area in this corridor, substantial replacement surface operations will be necessary to accommodate passengers in the South End and Roxbury areas. An extension of the Green Line from the Tremont St. subway in a new center reservation along Washington Street would provide an attractive alternate service. As noted before, the characteristics of the Green Line type of service, including close stop spacing, improved operating speeds, and high capacity would be well suited to the needs of this densely developed, close-in residential and commercial area.

4. Jackson Square Extension. The Huntington Avenue branch of the Green Line is presently composed of two segments of widely different character. The inner end is on reservation and serves a densely developed institutional area, while the outer end is located in a narrow street, in commercial and residential districts. Proposals have been made to abandon service on the outer end of the line to avoid the problems of the street operation. The CASS Stage 1 recommendations call for construction of a terminal and bus transfer facility in the vicinity of the intersection of Huntington and South Huntington Avenues. Later stages of the System II and System III solutions call for extension of the Huntington Avenue line to Brookline Village Station on the Highland Branch, but these are not recommended at this time.

   Another alternative, and probably a much less expensive one, would be to extend the Huntington Avenue line from the Stage 1 terminal at South Huntington Avenue to the new Orange Line station at Jackson Square via the planned new Washington Park Boulevard. This extension should be co-ordinated with proposed street widening and renewal projects in the area. Properly planned, the entire line

could be in center mall reservation from the end of the present reservation at Brigham Circle to Jackson Square.

This re-routing would permit passengers on the new Orange Line to easily reach destinations along Huntington Avenue and would improve the balance of traffic along the Green Line, in addition to providing an attractive service to residents along Washington Park Boulevard.

5. Boston College Extension. The present terminus of the Commonwealth Avenue branch of the Green Line is located at the Boston-Newton boundary near the intersection of Lake Street. Although this point is referred to by the Authority as Boston College Station, it is in fact some distance from the center of the college campus. A relatively short extension of this line along existing center reservation in Commonwealth Avenue, and into a simple end point in the center of the campus would not only benefit many faculty, students, and visitors to this growing educational institution, but in addition would serve more local residents. It is proposed to retain the present Lake Street yard as an operating facility, but to operate virtually all of the service through from the subway to the campus.

6. Other Improvements. There will be a number of miscellaneous improvements that should be included in a Stage 2 Program especially if (as seems likely) none of the proposed system solutions is adopted in its entirety.

   Typical of such improvements would be complete line control capability from the Authority's Dewey Square Operations Center for both Green and Blue Lines, cab signalling and train control for the Blue Line, and further improvements along the surface reservations in conjunction with local communities.

LONGER-TERM CONSIDERATIONS

Planning must be open-ended. The CASS project, completed with the publication of this report, must successfully provide a long term element as an integral part of the Authority's continuing planning program. It is the goal of the long range program to accomplish the following four levels of achievement:

1. To point out those technological changes which can be foreseen to be relevant to Inner Cities services;

2. To provide maximum flexibility in choosing the exact mix of technologies to be employed in the long range;

3. To fix a basis for decision making which will enable a current decision to be made without stifling future possibilities;

4. To provide information needed to insure the compatibility of all long-term alternatives with short-term needs without closing out options.

It is the purpose of this chapter to discuss the technologies which have the greatest potential for the MBTA, as well as their implications for service to the Inner Cities Area, and to point out those courses of action which the MBTA may take in determining the long range services to be provided in the Inner Cities Area.

It has become clear in this study that the optimal mix of modes for the Inner Cities Area in 1990 cannot be precisely determined in 1970. The most important single assumption about the future of the MBTA services to the Inner Cities concerns the nature of services to be offered. It is not envisioned that there will be reliance on one method of providing transit services; in all probability, there will gradually be instituted a mixture of modes into MBTA services which will have somewhat greater flexibility in serving patrons than is presently available. The principal concern is with the projected Inner Cities service provisions and needs for each mode and how these bear directly upon the decision to direct future planning efforts.

The remainder of this discussion is devoted to detailing the modes of public transportation which have been foreseen to be of potential utility in serving Inner Cities patrons. It will focus on the desirability of deployment of one particular mode upon the investment decisions concerning other modes. In this way, the stage will be set for discussion of specific courses of action which the Authority might undertake to anticipate rapid changes in available hardware, and to incorporate newly designed elements. The long term program for the Inner Cities is thus seen as a method of determining the optimum combination of services in a staged program of study, development and implementation over the next twenty years.

Choices between modes in specific geographic areas will be of concern for several years to come. It is probable, however, that the choices will be made from the technologies which are presently observable, in spite of the fact that several are not yet operable. The elements which are listed below include the known technologies from which the decisions will be made for providing services to the region. Certain of the services will be discussed subsequently in terms of specific relevance to the needs of the Inner Cities Area.

The network of public transportation services which will be operating in 1990 will be comprised of four elements, each of which contains several possible modes of service.

ELEMENTS OF PUBLIC TRANSPORTATION NETWORK FOR 1990

A. RAIL VEHICLE WITH DOWNTOWN DISTRIBUTION CAPABILITIES

1. High Performance Rapid Transit
2. Bi-Powered Commuter Rail
3. Streetcar-Subway

B. BUS WITH DOWNTOWN DISTRIBUTION CAPABILITIES

1. Inter-Neighborhood Dual-Mode Bus
2. Regional Express Bus
3. Intra-Downtown Bus

C. REGIONAL SERVICE TO DOWNTOWN TERMINALS

1. Commuter Rail
2. Regional Express Bus
3. Ultra High Speed Technology, e.g., Air Cushion Vehicle

D. FEEDER DISTRIBUTION FACILITIES

1. Intra-Neighborhood Bus
2. Point-To-Point "Capsule" Technology
3. Moving-Belt Technology

It is the primary function of this section to review the known parameters of each of these elements, in order to establish a basis for prediction of their future inter-relationships.

A. RAIL VEHICLES WITH DOWNTOWN DISTRIBUTION CAPABILITIES

The existing system of services which are provided by the Authority for the region is heavily focused on rail vehicles. The existing investment means that certain assumptions concerning future investments are severely constrained. Improvement possibilities chosen by the MBTA already include overhauling the existing system, thus it appears reasonable that rail vehicles will be retained with substantia

improvements and will be expanded into areas of demonstrated demand. Certain of the capabilities of specific types of rail vehicles should be mentioned, however, to demonstrate their relative adaptability for service to the Central Area.

1. High Performance Rapid Transit. This form of service is well-known to regional residents as to the focus of the services presently supplied by the MBTA. The high performance rapid transit lines are comprised of the familiar third rail subway lines which focus on the downtown retail center, lines which are currently in the process of being rebuilt and extended into new areas of service. Major portions of the Central Area are served by these lines as a staple of fast access. These services will most probably form the nucleus of services supplied by the MBTA for the foreseeable future. Much of the improvement potential for Central Area services is based on the existence of these lines and capitalizes on their existence by feeding the rapid transit stations or by supplementing the services they offer.

2. Bi-Powered Commuter Rail. A major supplement to the existing rapid transit system would be the addition of rail equipment which is not limited to service where third rails already exist, but which would be capable of operating on the existing rapid transit network, including the subway tunnels. This equipment would extend the services of the rail transit network outward toward suburban locations now served principally by rail vehicles which must stop at the edges of downtown. It would operate on third rail in rapid transit service and switch to internal combustion power in non-electrified service. Its merit lies principally in the provision of service in areas where the market has not been sufficiently developed to warrant installation of full-scale rapid transit, while leaving the option for gradually moving toward rapid transit operation when sufficient demand builds up.

3. Streetcar-Subway. The focus of this report on the Green Line streetcar-subway has demonstrated that its functions are well received and well utilized throughout its service district, much of which is concentrated in the Inner Cities. The utilization of this facility is enhanced by the many roles it fulfills: as a collector of Inner Cities traffic, as a line-haul instrument from specific outlying areas to Downtown, and as a major distribution facility for all transit services in the elongated physical shape which downtown functions have assumed. Its relative success has prompted further study of the levels of service it provides and their possible applicability in other portions of the Inner Cities. It has led to exploration of possible adaptations of non-rail services which could replicate its services in other areas where such a facility would be warranted. It has also led to the firm conclusion that the streetcar-subway services

must be maintained and constantly improved to a higher level in order to continue to attract riders.

B. BUS WITH DOWNTOWN DISTRIBUTION CAPABILITIES

One of the basic problems in providing bus access to downtown Boston is the inherent difficulty of using local streets for circulation. Downtown Boston, long renowned for the congestion of its downtown streets, is not capable of absorbing additional vehicles on the streets. Nonetheless, in certain instances, there appears to be a significant desire for bus access to downtown and for circulation on the same vehicle to a variety of locations within the downtown area. The development of such a system will require intensive analysis and considerable effort for accomplishment.

1. Inter-neighborhood Dual-Mode Bus. One of the possibilities for downtown bus access with distribution capabilities is the dual-mode bus. Essentially, this consists of a bus which would have the capabilities of street collection of patrons and some form of tunnel distribution in downtown. Such a vehicle has yet to be invented, the principal difficulties being a propulsion system which would be acceptable in long stretches of unventilated tunnels, and a guidance system which would enable the vehicle to pass through the constrictions of tunnels with maximum safety and control. These obstacles, which are being investigated already, will be overcome in time and will afford the possibility of instituting this type of service for specific neighborhoods. The desirability of such a vehicle in the MBTA system is worthy of consideration, particularly because of the service potential in the Inner Cities geographic sub-areas which are not likely to be well served by rail transit.

   In the development of rapid transit technology, it has become an accepted principle that buses should not come downtown, thereby competing with rail routes which have higher capacity. The major bus role is that of feeder service to rail transit lines. In fact, some buses actually do come into Downtown Boston, although they are kept strictly on the periphery. Charlestown (Bunker Hill), South Boston (City Point), South End (Tremont) are examples. Each of the above are specific situations in which the MBTA has recognized that these lines cannot be served in the feeder line-haul format.

Each of these cases serves as an example of neighborhoods which are too close to Downtown to benefit substantially from being routed over to a rail service. An additional example is provided by the City of Somerville, which has no direct rail access to downtown, but which is provided with numerous bus-to-rail transfer possibilities. Provision of a through bus connection for the City of Somerville could be likened to the situation in North Brookline, where the volumes on a single route are insufficient to warrant full scale high capacity rapid transit extension into downtown, yet the needs of interline riding plus downtown access are sufficient to warrant a single seat ride to downtown throughout the Inner Cities for a variety of tripmakers.

2. Regional Express Bus. The regional express bus, as operated in the Boston region, is a line-haul service from outlying suburban communities into terminal points in Downtown Boston. Where sufficient highway capacity exists, this form of service should be an appropriate element in the network of MBTA services. For the foreseeable future, it appears likely that the express buses, now operating on the Massachusetts Turnpike to the western suburbs, will continue to operate successfully. The toll schedule is presently a deterrent to the competing private vehicles on the Turnpike, and will probably continue to hold volumes on this thoroughfare to a reasonable level. The service being provided is limited by the distribution available in downtown Boston. Services are currently operating on local streets at the downtown terminal, and have to contend with local traffic which is severely congested at peak periods. An alternative downtown terminal would be desirable, especially if local street congestion could thereby be avoided. Two such alternatives for the existing service are suggested. The first is provision of terminal space in the proposed bus terminal at South Station. The second is provision of a downtown tunnel, possibly in conjunction with inter-neighborhood services. The first alternative would require an improved form of pedestrian distribution from the South Station terminal to downtown destinations. The second alternative would require vehicle design improvements which were previously suggested in order to enable successful operation of buses in tunnels.

3. <u>Intra-Downtown Bus</u>. One form of downtown distribution by bus is already in service. The Authority operates two bus lines in the financial district, which connect subway stations and rail commuter terminals to locations which are somewhat remote in a pedestrian sense from these access points. These buses compete with local traffic on downtown streets,and are not capable of effectively competing with automobiles in peak periods. Upgrading of such services would be extremely difficult unless some measure of control over automobile competition were effected.

C. REGIONAL SERVICE TO DOWNTOWN TERMINALS

This section is based on the justifiable assumption that some transit services will not be able to provide full downtown distribution services. There are three major modes envisioned in this category: commuter rail, regional bus, and speed-intensive new technology. Two of these modes will, during the planning period, have the technological capacity to perform distribution services: commuter rail as transformed through the Authority's BIPED Program (See Section A-2) and, regional bus through the development of dual-mode bus tunnels. Although both of these modes may become physically capable of providing a Green Line level of downtown distribution, it is a safe prediction that many services will still use terminals.

Terminals are utilized when it is uneconomic to have a line-haul vehicle do its own distribution. Historically, this kind of service has been associated with commuter railroads. In most cases, the vehicles, such as diesel engines, are incapable of going through non-ventilated downtown tunnels. Even in New York, where many regional lines are electrified, there is no major case of a commuter railroad being fully integrated with a subway.

Our concern for corridor to terminal facilities has two elements: (1) the probable routing of services to the terminal facilities, and (2) the need for a complementary technology to distribute pedestrians from the terminals to actual destinations. The following segment of this section briefly notes the services in question. The nature of the pedestrian technology needed to augment this kind of service is reserved for subsequent discussion.

1. Commuter Rail. Services currently being provided by commuter railroads in the Boston metropolitan area must be regarded as impermanent for the long range, because public subsidies at the present level cannot be expected to be forthcoming for an endless series of years for the relatively low number of passengers carried. The alternatives to commuter rail service will most probably be either bus or rapid transit extensions. Rapid transit, because of the capital costs involved, cannot be expected to carry the burden, especially with low levels of projected ridership. One possibility may be the bi-powered rail equipment which can test markets with a new form of service. With few exceptions, the rail service now being offered or, possible through bi-powered equipment, would not affect the direct services of the Inner Cities neighborhoods. Indirectly, of course, any improvements to the rail network expands the access levels of all patrons who have access to the system, and thus the Inner Cities residents would benefit to the degree that outlying destinations were attractively accessible.

2. Regional Express Bus. Buses will continue to drop passengers off at Haymarket, and possibly at the projected North Station garage. More relevant to the CASS Project are the needs of buses coming in from the Western Corridor. Buses currently use the local streets for distribution, both in the retail center and in Back Bay. The City has expressed its opposition to such routings, and terminal points must be found that are mutually acceptable.

   One concept that deserves further serious consideration is to route all Western Corridor express bus service to a Back Bay terminal, and over a private busway to South Station. This busway could have very heavy usage. In the long term, dual-mode buses operating in inter-neighborhood service could use it as well as Turnpike Express Buses. In addition, long-term planning suggests that it may be desirable to establish some bus routes using the proposed Third Harbor Crossing. Again, South Station and Back Bay Station would be used as corridor terminals for this service, and the private right-of-way would be needed.

The private right-of-way would allow buses to get off the Turnpike, and discharge passengers. This cannot be done with the present limitations of the Turnpike and the location of the railroad right-of-way. Research has quite strongly pointed out that there is not space for such a Western Corridor facility at the level of the railroad tracks and the proposed Orange Line relocation. Further, even if there were space, westbound buses would still need means to get onto the outbound lane of the Turnpike. A tunnel under that highway would be prohibitively expensive.

3. Ultra High Speed Technology, e.g., Air Cushion Vehicle

One of the factors to be considered in the choice of technology for long range services is the possibility of a major break-through in long distance high capacity services. Although most such services are inter-regional, e.g., New York to Boston, it is not inconceivable that the development process may result in intermediate-range service possibilities capable of serving specific needs in the Boston region. The mode currently preferred is that of the Air Cushion Vehicle, which will serve to exemplify the potential of this type of service within the region.

The Air-Cushion Vehicle mode falls into the category of "regional to terminal" in its characteristics. The developers of the air-cushioned technology do not at this moment conceive of local service by this mode. Rather, it is only at distances of approximately seven miles that the exceptionally high speed is feasible. At shorter station spacings, the vehicle cannot reach cruising speeds, which makes its performance characteristics markedly different from modern express rail.

Local application would depend on several factors. The first application of this technology would probably come under the condition that a supporting way be built and financed by another agency. Local application of the mode, initially at least, would then take the form of additional utilization of a supporting way created for inter-city travel. The most promising application of this mode to the MBTA system is in the Southwestern Corridor, if the Boston to New York route is chosen to include Providence. It should not be ruled out that the far suburbs in other corridors could benefit from speed-intensive systems, such as the air-cushioned vehicle; however, it is not clear at this point that the demand from communities far enough from the core to benefit from the speed have sufficient downtown travel demand to justify the actual construction of express service of this kind.

It can reasonably be concluded that air-cushion, speed-intensive technology has little place in all but the most remote sections of the Inner Cities. It would, in any event, benefit Downtown if a terminal were provided there.

The most important fact concerning its downtown operations is its incompatibility with all modes presently planned for the Authority's use. The required space for its beamway rules out any combined usage of expensive downtown tunnels. Further, the economics of a high-speed (over 150 MPH) vehicle suggest strongly that it cannot be used effectively in long downtown distribution segments. The regional vehicle will most likely utilize one, and at most, two downtown terminals. The downtown internal distribution system would be expected to function in place of direct-from-vehicle distribution.

D. FEEDER DISTRIBUTION FACILITIES

This section deals with feeder and distribution services which are not provided in other modes of travel. Specifically, it covers access to and from downtown oriented services, including both ends of the trip. It also includes services which are presently somewhat incidental to the feeder distribution functions. These services, commonly kmown as "intra-line riding", are in some communities, the major form of service utilization by MBTA patrons. In covering this subject, specific note has been taken of developing technology, in terms of the possible changes in equipment which will improve the efficiency of such services to both rider and operator groups.

1. Intra-Neighborhood Bus

The major form of feeder distribution service currently being operated by the Authority is the intra-neighborhood bus. This form of service is found throughout the Inner Cities and provides access to rail rapid transit stations from throughout the neighborhoods through which the rail lines pass. The web of services provides a major source of patrons for the high capacity lines, without which the rapid transit line capacity would be severely impaired. An extremely important policy of the Authority has resulted in the connection of each bus line to at least one rapid transit station, thereby assuring the continuation of this feeding process. This policy has two positive side effects:

(a) The reverse of the bus feeder process is a distribution function which is essential for a complete network of transit access to all areas of service.

(b) Through interconnected bus services at rapid transit terminals, it is possible to travel in many directions throughout the Inner City, as for example, to travel cross-town, rather than into downtown Boston and then outward to reach a desired destination. This form of service is particularly advantageous if traffic volumes warrant a high level of service on a single routing, and can be quite inconvenient for patrons if such a level of service is not warranted by the volume of traffic demand.

One hopeful improvement in bus feeder service is the proposed "dial-a-bus" system, which combines certain of the advantages of high-frequency bus service with the personalized service of a taxi, at a modest cost to the patron. This service will employ existing technology in its initial form in monitoring and dispatching vehicles, and will gradually be adapted to computerization for more extensive and complicated systems. The benefits of such service are particularly apparent to those patrons and potential riders who live at a substantial distance from existing high-frequency bus routes and for those who ride periodically and generally not in peak periods when service levels are somewhat higher. As an improvement upon the existing feeder services, large numbers of residents of the Inner Cities, particularly those who reside in the Inner Cities by choice and have not access to an auto, will benefit from an enhanced availability of public transit services.

2. <u>Point-to-Point "Capsule" Technology</u>

More than any other element in this discussion, a system of point-to-point capsules could dramatically change the way people move about a limited area, such as downtown Boston. In contrast with the discussion of line-haul vehicles which perform downtown distribution, such as the streetcar-subway, the capsule works on a different theory. In its ultimate application, each corridor would provide fast line-haul services to one or two downtown terminals. From each of the downtown terminals, passengers would be able to transfer to a capsule, which would go non-stop to a final destination.

Because the system would be automated, it is theoretically possible that small groups of people would be carried efficiently from station to station in the downtown area without stops in between. At low volume hours, the number of way stops could be simply minimized, with the capsule picking up passengers to keep headways reasonable.

Certain services are already corridor-to-terminal in nature and are likely to remain so. Express Bus, commuter rail and rapid transit express services all tend to have long station spacing, and a great need for complementary movement systems. Each of these services, which do not attempt full distribution, would benefit from a direct access to a capsule system.

A possible network basis for such a system is the Green Line, if utilized solely as a capsule-supporting way. This hypothetical network would serve the existing rapid transit lines in the same manner as the Green Line now does, but would have the potential of additional intermediate stops.

Automated capsules, however little we know about them today, should not be considered as only a long-term solution to many problems. On the other hand, they should not be utilized to perform services that could as well be provided by existing modes. The concept has some immediate and valid appeal where existing modes are inadequate. From South Station, Back Bay Station, Airport Station and several other points, there are clearly existing travel desire lines, requiring a transfer in any event. A capsule interface at these points would give this new mode a chance to demonstrate its potential.

This report supports the concept first put forth by a Massachusetts Institute of Technology group several years ago--that the automated capsule concept should be tested on a full-scale basis at Boston's Logan International Airport. This would be an excellent proving ground, without dislodging a service that already exists for an untested one. Logan Airport is developing into a multi-node area. Through rapid transit service that interfaced well with the planes and parking areas would require a new alignment, and could require as many as six stops for the airport alone. Full collector service would therefore not be economical nor even feasible for the MBTA using conventional rail technology. The present shuttle bus gets bogged down in traffic during peak periods.

An automated capsule system would serve the Airport well. Patrons at the New Eastern terminal would be able to board an elevator-like cubicle, and press the button marked "MBTA" or "Subway to Boston". The capsule would then proceed either directly to the Blue Line Station or proceed with a minimum of intermediate stops. The transit patron would be given fast service, although a transfer would be involved. It is within the realm of possibility that the people-mover could be routed to make actual across-the-platform Blue Line connections, although new fare collection methods would be required for such a scheme.

Analysis of the total capsule scheme all reveals one basic point--the through service attained by some passengers is lost for some other group of passengers. Turning the Green Line tunnels into a capsule system would greatly benefit the intra-downtown rider, and the express rider seeking downtown distribution, but the existing Green Line riders would not have gained. What they may gain in travel time has been lost by the necessity of transferring. Since approximately 85% of the Green Line riders with downtown destinations do not make any transfers, many of these people would lose seriously by any attempt to install an intra-downtown capsule system in place of the through service.

Finally, it should be noted that there are still serious problems concerning the potential capacity of capsule systems, especially at heavy transfer points such as Park Street. If all westbound Red Line riders were to transfer to capsules for the Back Bay, the volume would necessitate that the capsules move out in train formation toward the Back Bay. The volumes are so great that a "train" solution requires long trains, fast acceleration and high efficiency design. It would appear that the best long-term utilization of the Green Line tunnels is by fixed-rail vehicles.

3. Moving-Belt Technology. There are many untested aspects about capsule systems. It appears difficult at the present time to envision an entirely new system superimposed upon the present systems of movement in Downtown Boston. It may therefore be more readily acceptable to explore modes which are capable of evolution toward higher levels of technology at a later date. Development and application of relatively simple systems reduces the inherent difficulties of replacing known technology with unknown and uncertain new systems, but permits the potential of such technology to be explored.

A moving belt system for pedestrians is a relatively simple concept which has been tried in several settings. Throughout the development of CASS, constant contact has been maintained with the Boston Redevelopment Authority, which has a federal grant to study the engineering feasibility of a moving belt system from South Station along Summer Street to Chauncey Street. This system, as presently conceived, could be of immense value to the MBTA in providing improved distributional capabilities for downtown. Such moving belt systems are not unknown. In several air terminals and shopping centers, moving belts have been utilized to good effect in transporting substantial numbers of pedestrians relatively short distances. The capabilities of these systems appear to be such that they are inapplicable as a total solution to a system as large as the airport, but that they have strong potential for application in situations requiring shorter distance movements.

The most appropriate place for this kind of movement system is in Downtown Boston. Service into the financial district would be substantially benefitted by such improvements. A moving belt extending from State Street Station into the Post Office Square Area would be one example. A movement system from South Station toward Franklin and Federal Streets could be incorporated into the proposed Summer Street Renewal Project. Both would support and feed upon the existing rapid transit network and would help alleviate the need for additional rail transit service into that area for some time into the future.

In reviewing the corridor-to-terminal needs of several transit services, one fact has become increasingly evident: there are several points in the downtown area that will have great need for special distribution services. Commuter and rapid transit buses, and speed-intensive technology strongly point up the need for complementary technology for moving pedestrians. At present the rail facilities of Back Bay and South Station stand out most strongly. The future roles of North Station and Haymarket are slightly less clear, but the importance of the southern terminals is self-evident. The terminal category, which describes stations that do not provide full distribution, applies as strongly to proposed Back Bay and South Station transit facilities as it does for existing rail services. If it is legitimate for new lines to sacrifice coverage for line speed, which dictates long station spacing, then the new stations will require supplementary access by pedestrian movement systems. Back

Bay and South Station have promise as major intersections of modes of transit. Both will have a full variety of services feeding into them. Both are located somewhat on the periphery of the business districts they support. These two stations serve as the best example of the need for developing complementary people-moving technology.

The concepts recommended for further examination by the Authority are not limited to those listed in the above discussion. The development of new technology within the next twenty years will open up new opportunities for better serving certain difficult areas within the MBTA territory, once this new technology has been proven feasible. Wherever possible options should be left open for future application of new technology.

THE INTERRELATION OF DECISIONS: BIPED AND THE BLUE LINE

The MBTA Planning and Development Department has been conducting a research project on a concept known as BIPED (an acronym for Bi-Powered Equipment Development). This study was undertaken to find a method of providing rapid, low cost transportation to middle and outer sections of the MBTA service district to replace existing railroad commuter services, and to reduce the need for expensive electrified rail rapid transit extensions in areas of relatively light demand. The concept is similar to that of a demonstration project now being carried out on the Long Island Rail Road, where an electric commuter car has been adapted for self-propelled operation when travelling beyond electrified territory, using a gas turbine-electric drive.

On the MBTA,the concept would be applied to the smaller rapid transit cars which would operate through the downtown subways. The study is still in its preliminary stages, but if such a vehicle can be proven feasible, there would be several good areas for BIPED service in the MBTA territory. The most likely area for initial application of such service would be the new Orange Line, where service could be provided beyond the presently planned northern terminal of the electrified line at Oak Grove, to the present terminal of the railroad commuter line at Reading. This would eliminate the need for railroad shuttle service between Oak Grove and Reading, and avoid a passenger transfer at Oak Grove.

Another attractive application for BIPED service would be on the Boston and Maine Railroad's eastern route,to provide express service to downtown Boston from Pines River or beyond, utilizing the Orange Line rapid transit tracks from Sullivan Square in Charlestown to downtown Boston via the Washington Street subway. Pines River is the area proposed for a new terminal for the Blue Line, one mile beyond its present terminal at Wonderland in Revere.

The CASS study has already concluded that construction of an express rapid transit line from Pines River to connect with the Blue Line at Airport Station could not be justified due to its cost (See Volume IV, and Chapter 4 of this volume). Such an express service might well be provided by BIPED vehicles on the B&M route. If this does indeed prove feasible, then the extension from Wonderland to Pines River might not be needed, since this extension would then be attractive primarily to local riders, not destined for downtown points.

It has clearly been established that the major source of growth for the Northeast Corridor lies beyond the area currently covered by MBTA services. Traffic research has demonstrated that accommodating growth in this corridor is essentially a question of the most effective way of capturing the corridor trips which start or end outside the Inner Cities area; that is, north of Revere. The research has pointed out that the most critical element in intercepting these trips is a highly-developed, carefully designed highway interface. For this reason, highway improvements in the area, such as completion of the proposed connector from I-95 to Revere Beach, will become essential to either of the alternative methods of providing rail service to Pines River.

Research has also pointed out that riding without transferring may be more important than express service. For this reason, bi-powered service may become more appropriate for service to areas presently served by the Boston and Maine Eastern Route, and for riders seeking improved downtown distribution available on the Orange Line. Others will obtain access to either of the alternatives at the Pines River transit-highway interface.

It is clear that the BIPED concept is applicable, but the details of its utilization are not clear. It is not possible to determine at this point whether the Authority BIPED Program will develop into an economically feasible type of service, and if so, what its exact application will be. This will depend on the following factors:

1. The actual field-tested operating costs of BIPED

2. The comparative costs of using Boston and Maine lines vs. extending the Blue Line to Pines River

3. The physical requirements of vehicle design.

These factors will be more fully examined as part of the continuing Authority research program.

THE INTERRELATION OF DECISIONS: FEEDER BUSES AND DUAL-MODE BUSES

Many factors combine to affect the relative competitiveness of bus routings and actually determine whether a bus would serve its neighborhood better by being routed to a rapid transit line, to a peripheral downtown destination, or routed into a downtown distribution tunnel. Bodies of water, natural barriers, or simply a lack of adequate feeder roads can affect such decisions. This study has conceptually established the desirability of recreating a network of through services to downtown from close-in neighborhoods and communities. At the same time, the study recognized the technological impediments to doing so.

This report takes the position that the long-term program of the Authority must become increasingly concerned with raising the quality of services for existing Inner Cities riders. To do this, it is assumed that investments must be carefully designed to avoid ruling out long-term answers which could capitalize on evolving technologies. The new systems which now would appear to benefit the greatest number of residents of the Inner Cities are the dial-a-bus and the dual-mode bus. Dial-a-bus is most applicable in those areas where inter-neighborhood and feeder-bus services can be predicted to be the long-range solution to resident needs. Dual-mode buses will be most applicable to two specific kinds of services:

1. Inner-neighborhood service

2. Regional service with distribution

The two trip situations make use of the bus for two different rationales. In the case of regional bus, buses make use of relatively free flowing expressways to cover long line segments in minimized time. Areas like Wellesley and Waltham will probably have existing Middlesex and Boston bus routes combined and given direct downtown service over the Turnpike. Such a regional bus

service is well underway, and cannot be ignored in terms of long-range needs. Improved downtown distribution capabilities would improve the level of service offered.

The second use for a dual mode bus has nearly the opposite characteristics. Certain communities, like North Brookline, are so near the downtown area that relatively slow street service (which is coverage-intensive) actually provides superior service to a feeder-express arrangement which is speed-intensive. North Brookline has a kind of service which is a "bus" over dense apartment neighborhoods like Beacon and Commonwealth, and is a "train" as it distributes corridor patrons through the downtown tunnels. Other communities that would benefit from such service include the South End (after the loss of the present elevated Orange Line), the area northwest of the Lechmere terminal, and the full medical-educational complex spread out over the Fenway area. However, a dual-mode bus service has the important characteristic that it can serve any line that can use the streets to gain access to the tunnel entrance.

The downtown routing of the dual-mode bus has not been determined. Several options appear on the horizon but they are largely dependent upon the configuration of a vehicle not yet designed, because of propulsion and guidance difficulties which are not yet overcome. It is not inconceivable, however, that any new downtown tunnel could be closely tied into portions of the existing Green Line. Sections of this line which may be used for this purpose are as follows:

1. The Lechmere viaduct over the Charles River. This viaduct would provide grade-separated access to downtown from an area which does not presently have direct one-seat access to Downtown. With some modification, the facility could serve buses with appropriate guidance systems as well as it presently serves streetcars.

2. The Tremont Street Tunnel. This tunnel has been abandoned since 1962, but is still intact, and could provide a connection into the Green Line. If joint service of dual-mode bus and streetcar in the Green Line tunnel becomes feasible, this access may be extremely useful.

3. The Huntington Avenue Tunnel. This tunnel is one of the newest in the downtown network and has high geometric standards. If it appears desirable at some time in the future to remove this line and the complexities of Copley Junction from the Green Line streetcar-subway, it might be feasible to examine it as a routing for the dual-mode bus. Extreme caution should be exercised to avoid interfering with the distributional aspects of the line, however, replacement of streetcar service with a lower capacity bus network may not be an adequate solution for service to Huntington Avenue destinations.

The foregoing two illustrations of the interrelationships of decisions indicate the complexity of the problems which confront the Authority in providing improved services to the Inner Cities. The implications for policy are manifest; the Authority has begun the arduous process of evaluating the long-term needs of its riding public, and must devote considerable effort to exploring options which are feasible and which afford improvements to existing riders. The long-term implications of such improvements will become evident only when initial efforts toward improvements are undertaken. The improvements scheduled in Phase I of this study represent initial efforts which can be undertaken and which will move the Inner Cities toward better transit service, irrespective of long-term options which cannot now be foreseen.